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distances and velocities of stars in the Carrington zone
on the basis of spectrophotometric analysis

ACADEMICAL DISSERTATION

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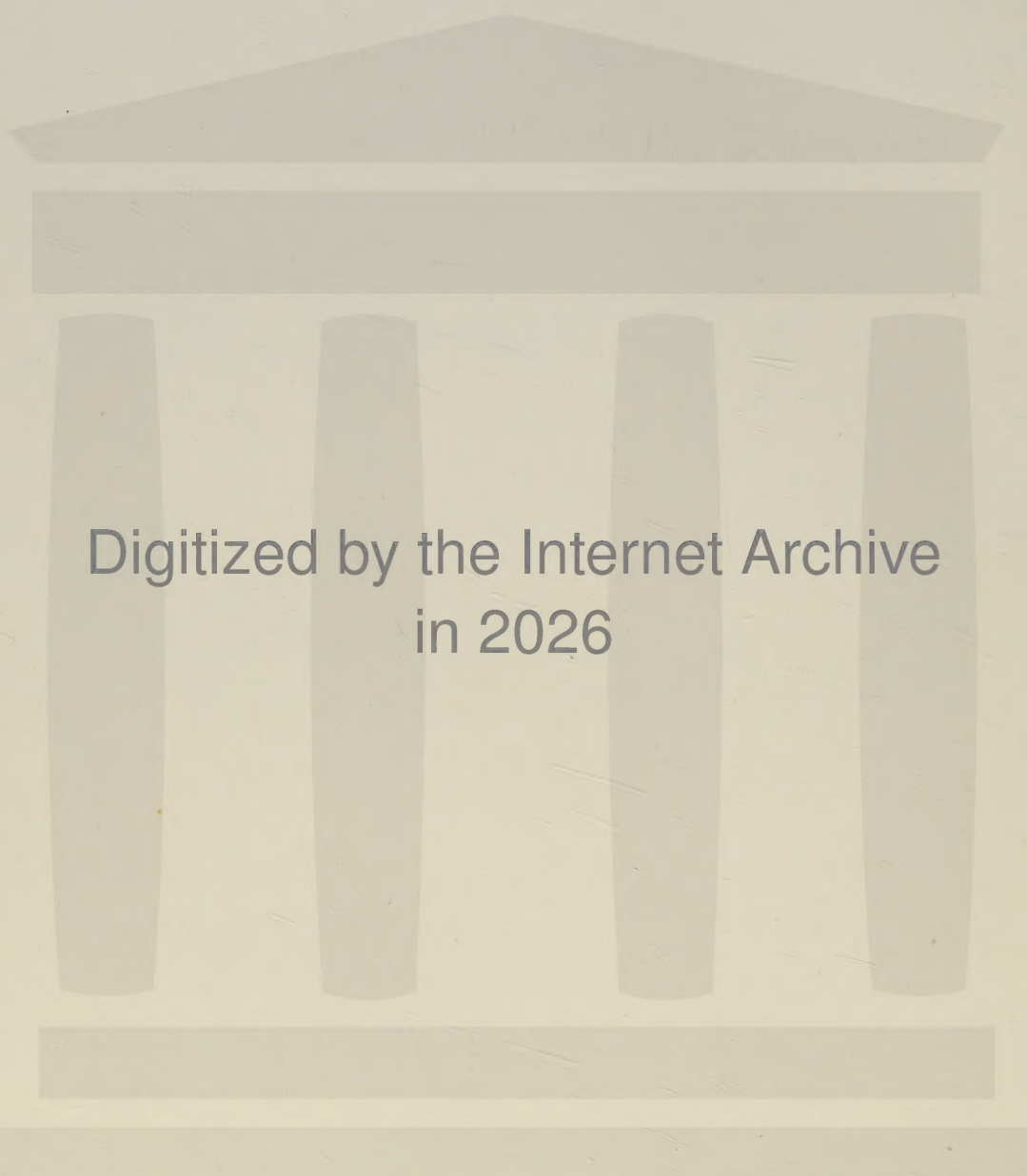
J. HARALD PETERSSON

FIL. LIC., ÖSTG.

BY DUE PERMISSION OF THE PHILOSOPHICAL FACULTY OF UPSALA TO BE PUBLICLY DISCUSSED IN THE
LECTURE HALL OF THE PHYSICAL INSTITUTION SEPTEMBER 10 1927 AT 10 A. M.
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

UPPSALA 1927

APPELBERGS BOKTRYCKERI AKTIEBOLAG



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Introduction.

In a series of investigations LINDBLAD has developed a spectrophotometric method for determining luminosities of late type stars. He found that there exists a correlation between cyanogen absorption in spectrum and absolute magnitude. For the white stars the method is not applicable, but for these it is possible to make an estimate of the magnitudes in another way, *viz.* by examining the appearance of the hydrogen lines. In fact, LINDBLAD has shown that the degree of sharpness of the lines is a measure of the luminosity of such stars.

The two methods have been extensively applied at Upsala by LINDBLAD to stars in the Greenwich polar zone. Up to the present two works containing spectral classification and determinations of absolute magnitudes for more than two thousand stars in this zone have been published by him.

As a complement to these investigations I have during the last years on the suggestion of LINDBLAD applied his methods to a part of the Carrington circumpolar zone with centre in the celestial north pole. For about 2000 stars I have thus determined spectral types and, for a great part of them, absolute magnitudes. The material is to be considered complete down to the apparent photographic magnitude 11.0.

Distances and velocities of the stars have been computed, by means of the photographic magnitudes and proper motions published from Greenwich. The density- and velocity-laws have then been studied. Combining results obtained by LINDBLAD with mine, it has further been possible to draw conclusions as to the distribution of stars of different types in successive layers of the stellar system parallel to the galactic plane.

Effective wave-lengths have also been determined at Greenwich for the zone here examined. The wave-lengths are yet not published, but through the great kindness of the Astronomer Royal, Sir F. W. DYSON, they have been put at my disposal before their appearance in print. They have been used by me for a discussion of their correlation to the spectral type and the colour-equivalent of LINDBLAD $\log E_G$.

The present investigation was carried out at the Upsala Observatory. I wish to express my gratitude here to the Director of the observatory, Prof. Ö. BERGSTRAND, for the kindly interest which he has always shown in my work and for

his valuable advice. It is also a pleasant duty to express to him my deep sense of obligation for my engagement at the observatory as assistant, which made it possible for me to undertake this investigation.

My thanks are also due to Prof. H. VON ZEIPPEL for his kind helpfulness during the time which I have spent at the observatory, and for his excellent, valuable lectures on theoretical astronomy.

To Prof. B. LINDBLAD I wish to express my very great indebtedness for my introduction into the part of astronomy here dealt with. On his suggestion this investigation was begun, and his lively interest in its successful completion could always be counted on. It has been an inestimable advantage, in our daily intercourse, to receive his advice and criticisms and to meet with new fruitful ideas. For this and for his friendship, which I have enjoyed during the past years, I wish to express my warm thanks.

I am further under obligation to Dr. K. LUNDMARK for his helpfulness in various respects. For the same reason I am indebted to Mr. S. ASKLÖF and Mr. C. SCHALÉN as well as to other members of the staff of the observatory.

For his kindness in sending me the effective wave-lengths mentioned above I wish to express my great gratitude to Sir F. W. DYSON, Greenwich.

I will also express my thanks here to Mr. J. B. NICHOLS, M. S., for a revision of the present paper from a linguistic point of view.

CHAPTER I.

Apparatus. Photographic plates.

The position in the sky of the tract investigated is very favourable for work at Upsala, the latitude of which is $59^{\circ} 51' 29''.4$.

The arrangement of instruments for obtaining the photographs is the same as that used by LINDBLAD. Thus, an objective prism of $9^{\circ}.7$ refracting angle is mounted in front of one of the two 15 cm triplet cameras of the Zeiss-Heyde astrograph of the Upsala Observatory. The focal length of the instrument is 150 cm. The distance between the hydrogen lines $H\gamma$ and $H\epsilon$ of the spectra on the plate amounts to 1.4 mm. Between these wave-lengths the images are in rather sharp focus for different parts of a plate of size 16×16 cm; in fact we are able to estimate the spectral type and to make measurements of relative intensities in the spectrum for the whole plate except for a very small part at one side, where the images are less distinct. It is important that the best focus be used. In order to give measurable images the plate must be situated within 0.2 mm from this point.

As the focal length varies somewhat with the temperature, it is necessary to redetermine it occasionally. The difference in focal length in winter and in the warmer seasons of the year amounts at maximum to about 0.5 mm.

The portion of the sky here investigated is, as mentioned before, situated at the celestial north pole. It consists of four regions with their centres at Dec. $+85^\circ$ and R.A. at 0^h , 6^h , 12^h , and 18^h respectively. See Figure 1.

Every region is covered by a plate of the size 16×16 cm. It extends in declination between about 82° and 88° . The regions are photographed according to two principles. The plates of the one series were exposed for two hours, the plates of the other contain a sequence of images with decreasing exposure-times in the ratio $\sqrt{2}:1$. The longest exposure-time amounts to 40^m , the shortest to 5^s . From every region we have at least two plates, generally more. Imperial S. S. plates were used, with a hydroquinone developer.

The plates were taken during the period autumn 1924 to autumn 1925. They were measured in 1925.

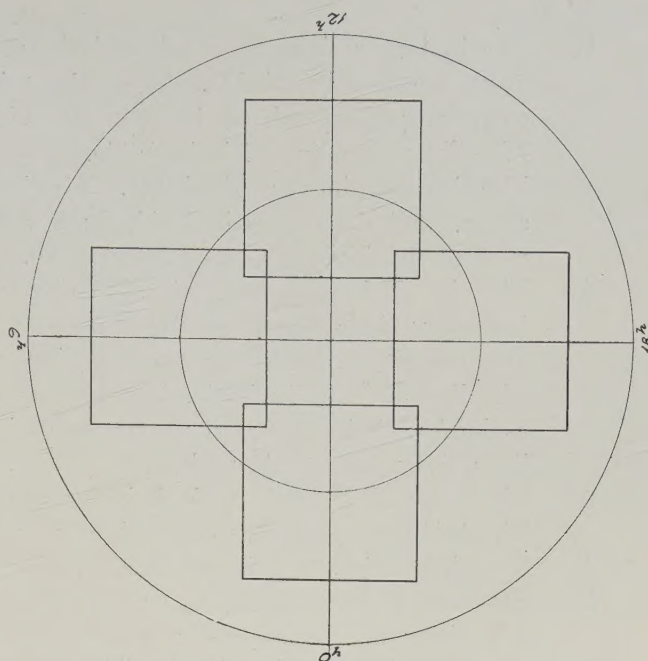


Fig. 1. The positions in sky of the regions investigated.

CHAPTER II.

Spectral classification. Luminosity classification of A stars.

1. The scheme of spectral classification used here is given in LINDBLAD'S "First paper", Nova Acta etc.¹ For the sake of completeness it is reprinted in the present paper. The analysis of the spectra is a modification of the Harvard classification.

¹ B. LINDBLAD, Spectrophotometric determinations of stellar luminosities, Nova Acta Reg. Soc. Scient. Upsal., Ser. IV, Vol. 6, No. 5, 1925.

Spectral Type

- B The hydrogen lines are weak and sharp. The helium lines $\lambda\lambda$ 4026 and 3819 are faintly visible. The colour is decidedly low (estimated by comparing the patch of the spectrum to the red of $H\gamma$ with the region $H\epsilon-H\zeta$). The line K is invisible.
- B8 The helium lines are invisible. The hydrogen lines are at least fairly sharp, and the colour is decidedly lower than for corresponding sharpness of the hydrogen lines in type A0. The line K is invisible.
- A0 The line K is only very faint. The hydrogen lines are at their maximum intensity; their degree of sharpness may vary from one star to another. The colour can be rather advanced for stars with diffuse hydrogen lines.
- A2 The line K is well visible. The hydrogen lines are of the same strength as in A0; their degree of sharpness varies. Stars with diffuse hydrogen lines show often rather advanced colour.
- A3 The line K is well marked, but is still considerably weaker than $H\delta$. The hydrogen lines are only slightly weaker than in A0.
- A5 The line K is not quite as strong as $H\delta$ (appears often sharper than $H\delta$).
- F0 The line K is as strong as or somewhat stronger than $H\delta$.¹ The hydrogen lines are considerably weaker than in A0 but are still very conspicuous. The band G is invisible. (The colour is at least in the mean slightly more advanced for types A5 and F0 than for A0–3).
- F2 The band G is generally faintly visible but decidedly weaker than $H\gamma$. The hydrogen lines are well marked. The line K is very strong.
- F5 The band G is about as strong as $H\gamma$. The hydrogen lines are rather faint, and the colour is more advanced than in the preceding types.
- F8 This type resembles dG0, but the hydrogen lines are slightly more marked, and the contrast in the continuous spectrum at the band G is scarcely visible.

Dwarf stars.

Dwarf stars have weak cyanogen absorption and show generally strong arc line absorption at λ 3900 Å.

- dG0 The hydrogen lines are only very faintly visible, but $H\gamma$ and $H\delta$ are stronger than the calcium line λ 4227 Å, which is generally invisible. The contrast in the continuous spectrum at the band G between the blue and the violet begins to be marked, but is still not conspicuous.
- dG5 All lines except H and K are very faint. The line λ 4227 is about equal to $H\gamma$ and $H\delta$. The contrast at the band G is somewhat greater than in dG0.
- dG8 The contrast at the band G is somewhat greater than in the preceding types.

¹ There are stars which have a faint K line, though the spectrum in what concerns colour and the intensity of the hydrogen lines is similar to spectra of type A5–F. We use the notation F0[A2] or similar for such stars, the type within brackets characterizing the strength of the line K .

- dK0 The line $\lambda 4227$ is more plainly visible. The contrast at the band G is well developed.
- dK2 The line $\lambda 4227$ is well marked. The contrast at the band G is strongly developed.
- dK5 The line $\lambda 4227$ is very strong.
- dM The line $\lambda 4227$ is very strong and the colour is very much advanced. The region between $\lambda 4227$ and the band G is conspicuously weak compared with the neighbouring regions of the spectrum.

Giant stars.

Giant stars of types G8—K2 have strong absorption in the cyanogen bands, and also for the other types of the interval G0—M the difference of intensity between the standard region $\lambda\lambda 4227-4272 \text{ \AA}$ and the cyanogen region $\lambda\lambda 4144-4184 \text{ \AA}$ is algebraically greater for the giants than for the dwarfs of the same type. Giant stars have also relatively slight absorption at $\lambda 3900$ compared with the dwarfs of the same type.

- gG0 The hydrogen lines are about as strong as in dG0. The contrast at the band G begins to appear but is not conspicuous. The line $\lambda 4078$ can often be distinguished as a faint line.
- gG5 $H\gamma$ and $H\delta$ are very faint but are still somewhat stronger than the line $\lambda 4227$, which is often quite invisible. The contrast at the band G is somewhat greater than in gG0 but considerably smaller than in gK0.
- gG8 All lines except H and K are very faint. The contrast at the band G is well marked, only slightly smaller than in gK0.
- gK0 The line $\lambda 4227$ is often visible, though only very faint. The contrast at the band G is strong.
- gK2 The line $\lambda 4227$ is generally well visible. The contrast at the band G is very strong.
- gK5 The line $\lambda 4227$ is very strong. The contrast at the band G is very strong.
- gM The line $\lambda 4227$ is very strong. The titanium-oxide bands are visible. The contrast at the band G is generally very strong.¹ The hydrogen line $H\gamma$ can often be traced. The cyanogen absorption is very weak.

For every star of not too faint apparent magnitude we have two estimates of the spectral type, one from the plate with exposure-time 2^h and the other from the plate with exposures in series. The two estimations may be denoted by A and B respectively. The spectral type finally adopted is the mean of A and B . Generally A and B coincide. If not, greater regard has been paid to B than to A , as B rests on a whole series of spectral images. For the faintest stars we have only the classification A , and, of course, the adopted spectral type must, on account of this, be considered somewhat less certain. However, the classification

¹ Stars of type Mb or Mc show often rather small contrast at the band G .

is undoubtedly very reliable in this case too, a conclusion which follows from a comparison between spectral type and effective wave-length for different apparent magnitudes, as will be shown later.

2. LINDBLAD introduced a special classification of the A stars at an early stage of his spectral investigations. In order to obtain absolute magnitudes of A stars he originally¹ adopted a spectrophotometric method similar to that used for the stars of late types. (This method will be described in the next chapter.) He compared the densities of the spectral regions $\lambda\lambda$ 3895–3907 and $\lambda\lambda$ 3907–3925 and found correlation between exposure-ratio and absolute magnitude. This method was, however, soon abandoned and a luminosity classification on another basis substituted. This was first announced² in 1924 and has been described in detail in LINDBLAD's "First paper" as well as in his "Second paper".³ The classification, which embraces stars of types B8–A3, is made according to the varying sharpness of the lines of hydrogen, and, for stars with winged lines, according to colour.

Later some minor changes have been made in the scheme of classification.⁴ I give here the scheme according to a recent paper by LINDBLAD and SCHALÉN.⁵

τ : The hydrogen lines are very narrow, so that they are invisible or almost invisible at the present dispersion.

$\tau-$: The hydrogen lines are very narrow, but appear sufficiently clearly to be fixed without difficulty.

$\sigma+$: The hydrogen lines are somewhat wider, but do not increase materially in width from strong to weak images of a sequence.

σ : The hydrogen lines increase somewhat in width towards faint images.

$\sigma-$: The sharpness of the lines is less pronounced but is still noticeable. The colour is always low.

ρ : The wings of the hydrogen lines are strong. The colour is low.

μ : The wings of the hydrogen lines are very strong, and the colour may be very slightly more advanced.

$\kappa-$: The colour is perceptibly more advanced than in the preceding classes. The hydrogen lines are winged.

κ : The colour is considerably more advanced than in classes $\rho-\mu$. The absorption at λ 3906 due to arc lines of Si and Fe is often marked.

¹ B. LINDBLAD, Spectrophotometric methods for determining stellar luminosity, Mount Wilson Contr., No. 228, Astrophysical Journal, Vol. 55, 85, 1922.

² B. LINDBLAD, Note on the spectroscopic parallaxes of A-type stars, Astrophysical Journal, Vol. 59, 305, 1924.

³ B. LINDBLAD, Researches based on determinations of stellar luminosities (second paper), Nova Acta Reg. Soc. Scient. Upsal. (Volumen extra ordinem editum 1927), 1926.

⁴ C. SCHALÉN, Spectrophotometric determinations of absolute magnitudes of B and A type stars, Arkiv f. mat., astr. o. fys., Band 19 A, No. 33, 1926.

⁵ B. LINDBLAD and C. SCHALÉN, The luminosities, individual parallaxes, and motions of B and A type stars, Arkiv f. mat., astr. o. fys., Band 20 A, No. 7, 1926.

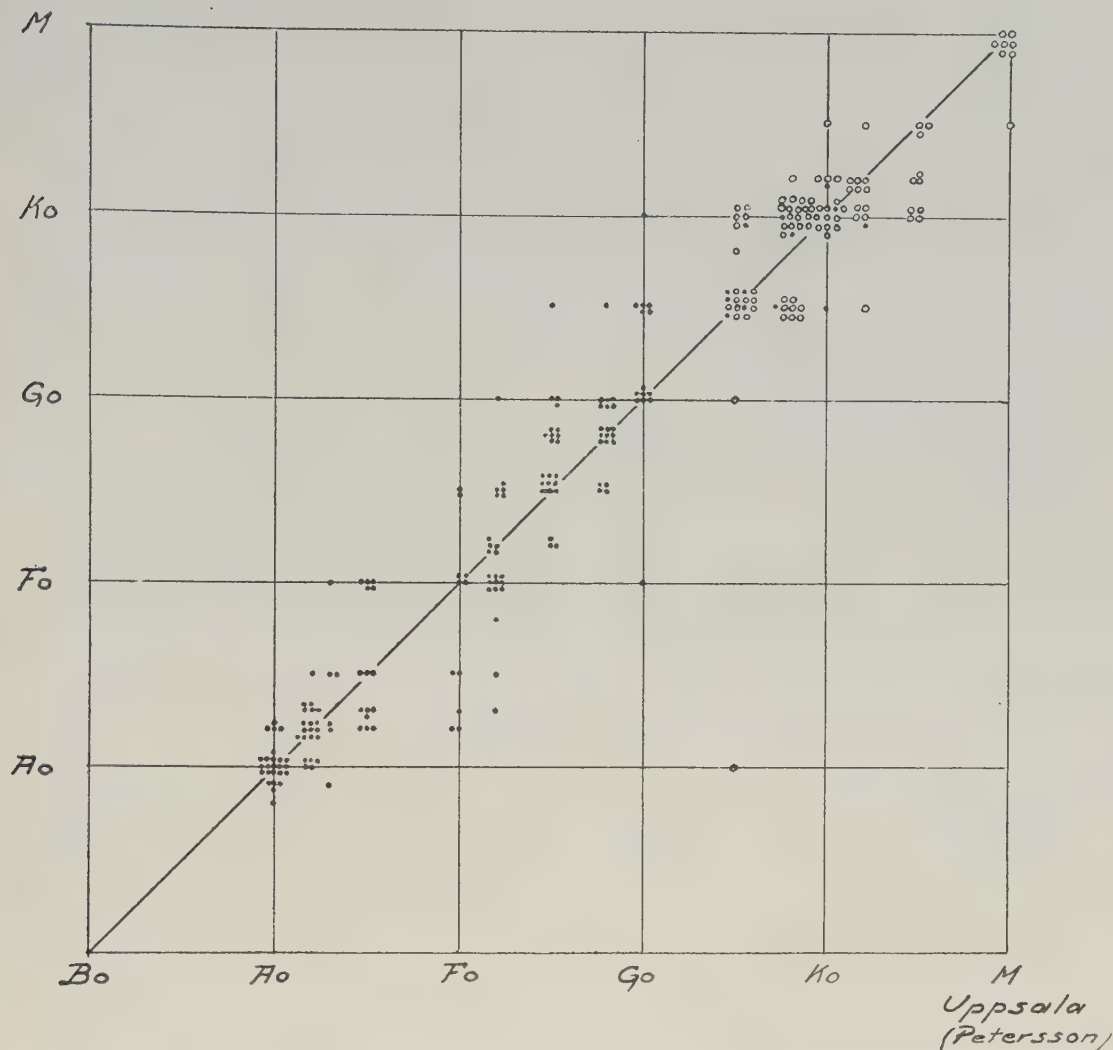
Harvard

Fig. 2. Relation between the classifications of Uppsala and Harvard (Draper catalogue).

In the present investigation the stars with the sharpest hydrogen lines belong to group σ . The fact that the groups with still narrower lines are not represented here is due to the relatively high galactic latitude of the investigated tract and the consequent absence of white stars of greatest intrinsic brightness. No B stars occur. The A-type stars most frequently found here are the π stars.

The luminosity classification of the B8–A3 stars is performed simultaneously with the classification in the Harvard system. The denotation for the luminosity group is added to the spectral type.

3. In the general catalogue at the end of this paper the spectral types according to Harvard (Draper catalogue) are given in the column "Sp. H." The whole number of Harvard spectra in the catalogue is about 260. As a comparison it may be mentioned that the number of spectra classified by me ("Sp. U.") amounts to about 2000. The stars with Harvard spectrum are in nearly all cases brighter than the apparent magnitude 10.0. The classification made at Upsala reaches considerably fainter stars, in certain cases stars below the 12. magnitude.

In Figure 2 the Harvard type is plotted against that of Upsala for the 260 stars mentioned above. The spectral types of the faintest stars are naturally not quite so reliable; nevertheless they have been included. Giants of type G0 and later are denoted by circles, dwarfs and stars of earlier type 3 than G0 by black dots.

It appears from the diagram that the agreement between the two classifications is very good, especially if we take into consideration the following circumstances. Both classifications have no intermediate steps between the spectral types A5 and F0, nor between G0 and G5. Furthermore the type G8 is used in the classification of Upsala but not in that of Harvard. This must result in a spreading of the type in question over the neighbouring spectral types of the Harvard classification.

A slight systematic difference seems to exist for the types F5, F8, and dG0 according to my classification. They are often classified in Harvard as belonging to somewhat later types.

CHAPTER III.

Spectrophotometric method for determining luminosities of late type stars.

In a paper cited in the preceding chapter LINDBLAD¹ showed that there exists a close correlation between absolute magnitude and cyanogen absorption in spectra of late type stars. The cyanogen bands used for the investigation were those with their first heads at λ 3883 and 4216. Especially the last mentioned absorption band, though weaker than the first, proved to be convenient. The amount of absorption was measured for a number of stars with known parallax in a way which will be described presently. Curves were then drawn showing the variation of cyanogen absorption, named $\log E_N$ by LINDBLAD, with absolute magnitude for different spectral types, as well as the variation of $\log E_N$ with advancing spectral type for constant absolute magnitude.

Later on a spectrophotometric measurement of the break in the continuous spectrum at the band G was introduced² in the analysis in addition to the estimation

¹ Mount Wilson Contr., No. 228, Astrophysical Journal, Vol. 55, 85, 1922.

² B. LINDBLAD, On the intensity-distribution in short grating spectra and objective-prism spectra as a function of spectral type and absolute magnitude, Monthly Notices, Vol. 83, 503, 1923.

of spectral type. The colour-equivalent thus obtained is called by LINDBLAD $\log E_G$. The relation between $\log E_N$, $\log E_G$, and absolute magnitude has been subjected to a close study in LINDBLAD's "First paper". The diagrams given were later revised on the basis of new data. The relations thus obtained are shown in the diagram Figure 1 of the "Second paper". The diagram gives absolute magnitude and spectral type for late type stars as functions of $\log E_N$ and $\log E_G$. It has been adopted by me in the present investigation for obtaining absolute magnitudes. The diagram is given here in Figure 3. From a recent paper¹ it appears that a slight correction ought to be applied to the curves of the diagram for $\log E_G < 0.3$, $\log E_N > 0.3$, *i. e.* for giants of F8 or G0 type. However, as I have no spectrophotometric determinations for these types, the correction might in this connection be left out of consideration.

In order to measure the amount of cyanogen absorption the following method introduced by LINDBLAD has been used. For each star of the one series of plates we have, as mentioned before, a sequence of images with decreasing exposure-times. The longest exposure-time is 40^m , then follow $28^m 18^s$, 20^m , etc., down to 5^s in the ratio $\sqrt{2}:1$. Let us denote the images in the sequence by the numbers 1, 2, 3, and the corresponding exposure-times by $t_1, t_2, t_3, \dots$. The spectral region most strongly affected by the cyanogen band with its first head at $\lambda 4216$ lies between $\lambda 4144$ and 4184 . The density of this region in a certain image was compared with that between $\lambda 4227$ and 4272 in the following images. The point in the scale of images for which the intensity of the last mentioned region was equal to that of the first one in the reference image, was estimated by interpolation to a tenth of an interval. If the exposure-time corresponding to this point is called t , the logarithm of the ratio $t_1:t$, denoted by LINDBLAD by $\log E_N$, is a measure of the intensity-fall in the spectrum at $\lambda 4216$, and therefore a measure of the amount of cyanogen absorption. According to the Schwarzschild law of density, $S = \varphi(I t^p)$, we have, for two equal densities S and S_1 and the intensities and exposure-times I, I_1 , and t, t_1 , the well-known equation

$$I t^p = I_1 t_1^p \text{ or } \log \frac{I_1}{I} = p \log \frac{t}{t_1} = p \log E_N$$

The scale-reading which corresponds to the exposure-time t can readily be converted into a logarithm, the unit of the logarithmic scale being $\log \sqrt{2} = 0.15$. As $p = 0.80$ for the plates used this unit will be 0.30 in the ordinary magnitude-scale. However, it is more convenient, as LINDBLAD does in his recent works, to keep $\log E_N$ expressed in the unit 0.15. In order to obtain trustworthy values of $\log E_N$ as many estimations as possible were made, starting with each image of the sequence as a reference image.

The measurement of $\log E_G$ is performed in a way analogous to that of $\log E_N$. The regions compared are $\lambda 4227-G$ and $G-\lambda 4383$.

¹ B. LINDBLAD, On the absolute magnitudes and parallaxes of bright stars determined by the cyanogen criterion, Kungl. Svenska Vetenskapsakad. Handl., Ser. III, Band 4, No. 5, 1927.

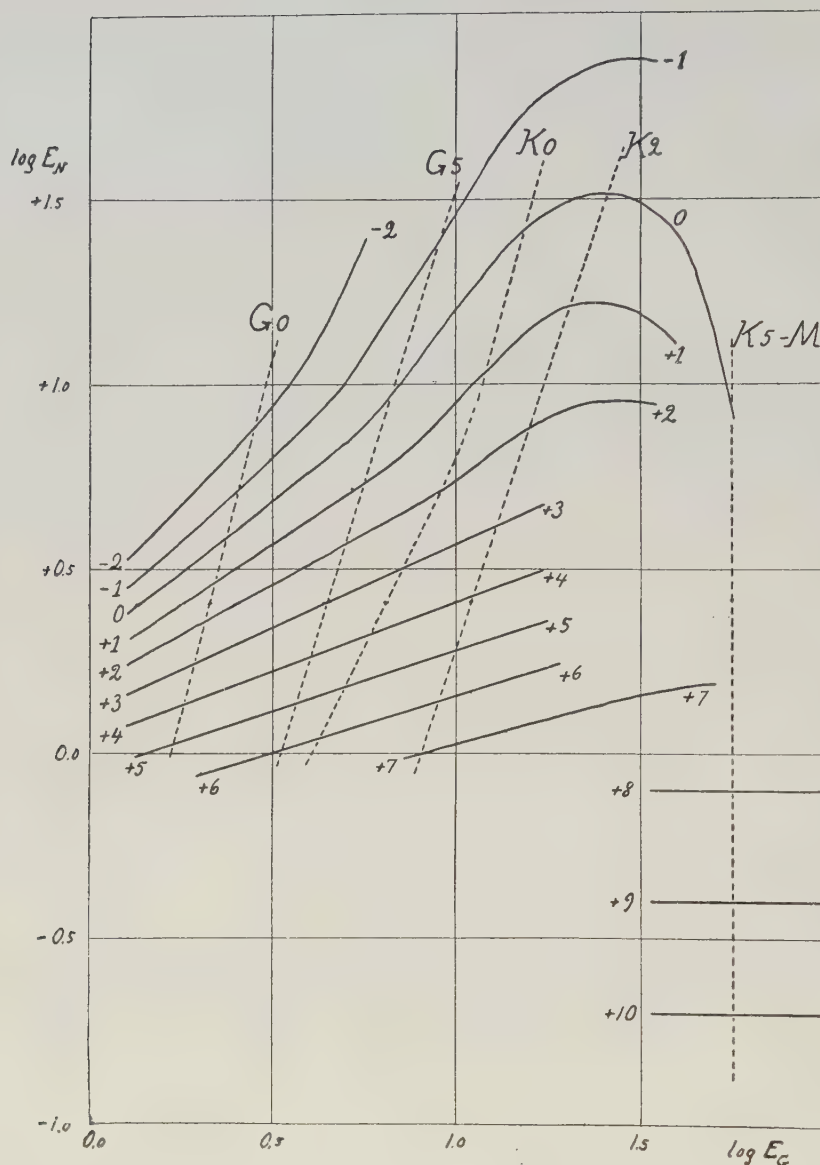


Fig. 3. Absolute magnitude and spectral type as functions of $\log E_G$ and $\log E_N$.

CHAPTER IV.

Colour-indices. Absolute luminosities.

1. Before absolute magnitudes could be deduced from LINDBLAD's relations between $\log E_G$, $\log E_N$, and the luminosity M (See Figure 3), it was necessary to ascertain whether my conception of the relative intensities in the spectra agreed with LIND-

BLAD's. Therefore I have measured exposure-ratios for about one hundred stars on LINDBLAD's plates and compared my measurements with the corresponding ones made by LINDBLAD. I find a slight systematic difference. The corrections to be applied to my values (P) in order to reduce them to the scale of LINDBLAD (L) are the following. (The logarithmic exposure-ratios are expressed in the unit $\log \sqrt{2} = 0.15$.)

$\log E$	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
L-P	0.00	-0.01	-0.03	-0.05	-0.03	+0.05	+0.11	+0.12	+0.08	+0.03	0.00

After applying the above corrections to my measurings of $\log E_G$ and $\log E_N$ the absolute visual magnitudes were obtained from the diagram Figure 3. Only those values of $\log E$ were used that rested on estimates from at least two spectral images.

The apparent photographic magnitudes of the stars in the Carrington zone were measured at Greenwich in the scale of Harvard Circular 180. The magnitudes have then in the present investigation been reduced to the International System by applying the corrections of Harvard Annals 71, 224, and of Harvard Bulletin 781.

Table I.

Star (B. D.)	C. I. (Parkhurst)	$\log E_G$	Star (B. D.)	C. I. (Parkhurst)	$\log E_G$	Star (B. D.)	C. I. (Parkhurst)	$\log E_G$	Star (B. D.)	C. I. (Parkhurst)	$\log E_G$
82° 201	1.72	1.80	83° 535	1.13	0.70	84° 513	1.00	1.13	85° 384	1.38	1.18
325	0.66	0.23	640	1.62	1.68	517	1.51	1.58	86° 17	1.21	0.92
498	0.59	0.67	84° 78	1.29	1.36	85° 19	1.22	1.29	79	1.24	1.48
703	1.50	1.48	269	0.28	0.08	63	0.50	0.00	113	0.79	0.67
728	1.09	1.08	274	0.47	0.66	80	1.58	1.72	275	1.16	1.08
83° 114	1.05	0.63	286	0.48	0.35	161	0.84	0.55	282	1.69	1.81
369	1.28	1.06	509	0.92	0.63	183	0.91	0.78	87° 51	1.75	1.72
512	0.59	0.00									

Table II.

C. I. (Parkhurst)	Mean C. I.	Mean $\log E_G$	No.
< 0.7	0.51	0.28	7
0.7—0.9	0.81	0.61	2
0.9—1.1	0.99	0.85	5
1.1—1.3	1.22	1.13	7
1.3—1.5	1.44	1.33	2
1.5—1.9	1.65	1.72	6

2. The distances of the stars are obtained from the inferred absolute visual magnitudes and the apparent photographic magnitudes just mentioned when we know the colour-indices. In order to determine these I have proceeded in the following way. A number of stars with measured $\log E_G$ in the general catalogue are listed in PARKHURST's catalogue of colour-indices in the Yerkes Actinometry.¹ (See Table I.) Means of $\log E_G$ and of PARKHURST's colour-indices were computed for successive intervals of the colour-index. Table II gives the means. The results of the tables are shown in Figure 4 as well. It appears that the relation between $\log E_G$ and PARKHURST's colour-index is linear. However, it is not colour-indices in PARKHURST's system which interest us at present but colour-indices Greenwich corrected photographic magnitude minus Harvard visual magnitude. In order to

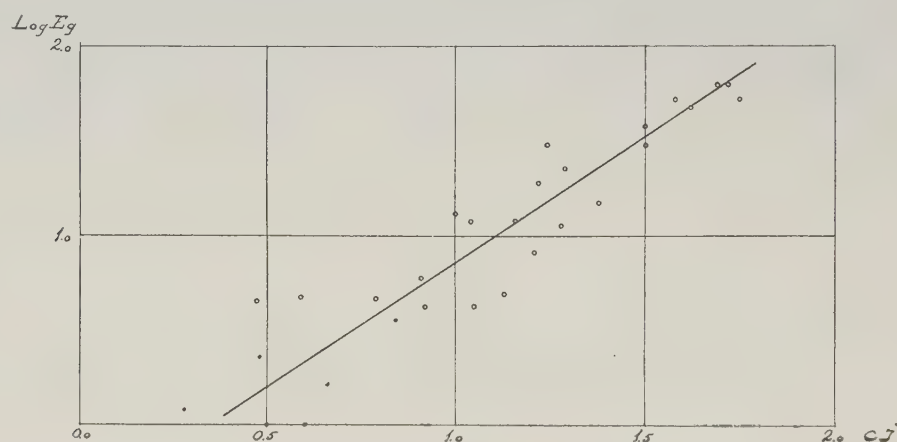


Fig. 4. Relation between $\log E_G$ and PARKHURST's colour-indices. $\circ$ Giants $\bullet$ Dwarfs.

connect the latter system with $\log E_G$ we use a relation deduced by LINDBLAD between the system Greenwich corrected—Harvard and PARKHURST's system. Table III gives the relation.

Table III.

Parkhurst	Greenwich corr.— Harvard	No.	Parkhurst	Greenwich corr.— Harvard	No.
0.00	0.00	—	1.20	0.88	48
0.59	0.44	43	1.39	1.13	39
0.78	0.67	30	1.58	1.23	34
1.00	0.80	74	1.79	1.28	16

Table IV. Inter-relations
of colour-systems.

$\log E_G$	Parkhurst	Greenwich corr.— Harvard
0.28	0.51	0.41
0.61	0.81	0.65
0.85	0.99	0.79
1.12	1.22	0.97
1.33	1.44	1.15
1.65	1.72	1.38

¹ Astrophysical Journal, Vol. 36, 169, 1912.

With the help of the values in this table a curve is drawn, from which the colour-index Greenwich corrected—Harvard may be obtained for a given value of PARKHURST's colour-index. The latter, however, corresponds to a certain value of $\log E_G$ which is to be taken from Figure 4. Thus we get the colour-systems of Table IV, which are valid simultaneously. The relation between $\log E_G$ and the colour-index Greenwich corrected—Harvard is illustrated in Figure 5. The points of the diagram lie very nearly on a straight line. The nature of $\log E_G$ as a colour-equivalent is thus evident. For every spectral group means of $\log E_G$ were then computed, after which the colour-indices desired were obtained from the curve Figure 5. In Table V columns three and four give mean values of $\log E_G$ and of the corresponding colour-index Greenwich corrected—Harvard for a given spectral group.

Table V.

Spectrum	$\overline{M}_{vis}$	$\overline{\log E_G}$	C. I. Greenwich corr. —Harvard	No.
dG0	4.5	0.24	0.40	62
dG5	4.8	0.44	0.50	18
dG8	4.9	0.62	0.62	9
dK0	5.3	0.73	0.70	5
gG5	1.0	0.66	0.65	46
gG8	1.0	0.81	0.76	45
gK0	0.8	1.04	0.93	25
gK2	0.3	1.39	1.18	6
gK5		1.75	1.44	13
gM		1.71	1.42	8

Table V contains colour-indices for only the spectral classes G0—M, a fact which is quite natural, as we have no measurements of $\log E_G$ for earlier types than G0. For the latter we assume the following values for the colour-indices:

A0 (except κ), colour-index = 0.0	F2, colour-index = 0.3
A0 κ , A2, A3, „ = 0.1	F5, F8, „ = 0.4
A5, F0, „ = 0.2	

3. The colour-indices of Table V are added to the visual absolute magnitude M_{vis} in every individual case that the magnitude has been obtained from the diagram Figure 3. However, for most of the late type stars we have, on account of their faintness, no measurements of $\log E_G$ and $\log E_N$ and thus no estimated magnitudes. For these stars we must adopt mean values. They have been computed by means of the estimated absolute magnitudes. The mean visual absolute magnitudes for types G0—K2 thus calculated are given in the second column of Table V. By

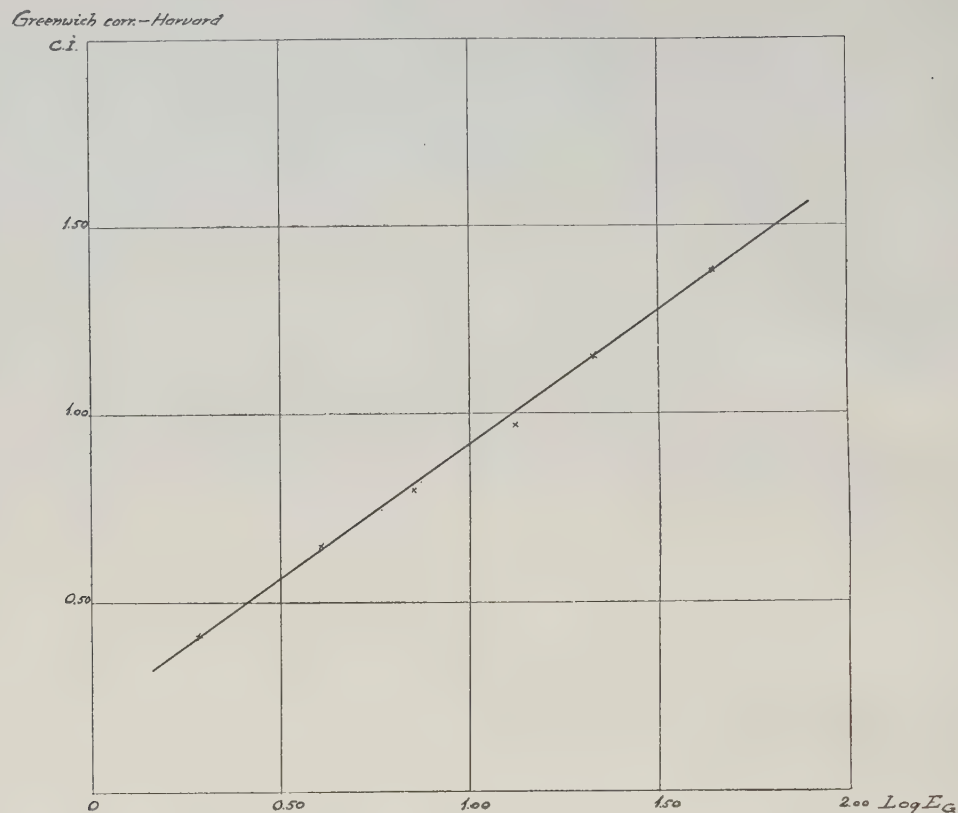


Fig. 5. Relation between $\log E_G$ and the colour-index Greenwich corrected photographic magnitude — Harvard visual magnitude.

adding the colour-indices of the table to M_{vis} we obtain the values of the mean photographic absolute magnitudes M_{ph} which are given in Table VI. The values corresponding to dK2—M, gG0, and gK5—M are hypothetical. The table contains also M_{ph} for the types A5—F8 taken from LINDBLAD'S "Second paper". The values of M_{ph} listed in Table VI are used for the computation of distances and linear velocities in cases where for some reason we have no spectrophotometric measurements of a star but only a spectral classification.

Table VI. Mean photographic absolute magnitudes of A5—M stars.

Spectrum	M_{ph}	Spectrum	M_{ph}	Spectrum	M_{ph}	Spectrum	M_{ph}	Spectrum	M_{ph}
A5	2.5	F8	4.4	dK0	6.0	gG0	(1.0)	gK2	1.5
F0	2.7	dG0	4.9	dK2	6.7	gG5	1.6	gK5	1.7
F2	3.1	dG5	5.3	dK5	(7.5)	gG8	1.8	gM	1.7
F5	3.7	dG8	5.5	dM	(8.0)	gK0	1.7		

Table VII. Mean photographic absolute magnitudes of A stars.

Class	A0	A2	A3
σ	0.2		
$\sigma-$	0.2		
ρ	0.9		
μ	1.0	1.1	
$\kappa-$	1.3	1.9	1.9
κ	2.5	2.5	2.5

The B8–A3 stars are, as mentioned before, divided in sub-classes. This division is, according to LINDBLAD, a luminosity classification. For the different sub-classes LINDBLAD has derived values of the absolute magnitude. (See Table VII.) These magnitudes were communicated to me by LINDBLAD at the beginning of my work. Later on LINDBLAD¹ and SCHALÉN have finished an investigation, from which it appears that we should assume values of M_{ph} which differ a little from those given in Table VII. However, at that time my work had proceeded so far that I thought it inconvenient to make any changes in my assumptions.

In Figure 6 frequency curves of the visual absolute magnitude M_{vis} are drawn for stars of late spectral types. The magnitudes have all been derived from the cyanogen criterion. N is the number of stars. It has been computed for successive magnitudes.

The division of the stars into giants and dwarfs is evidently very pronounced for the types G5–K0. For type G0 we have no maximum corresponding to the giant group. This is due to the excessive rarity of the gG0 stars in the present data and further, when they occur, to their faintness, which does not permit any spectrophotometric measurements but only spectral classifications. In fact, it is very striking how few are the stars of type gG0. Among the 182 G0 stars which

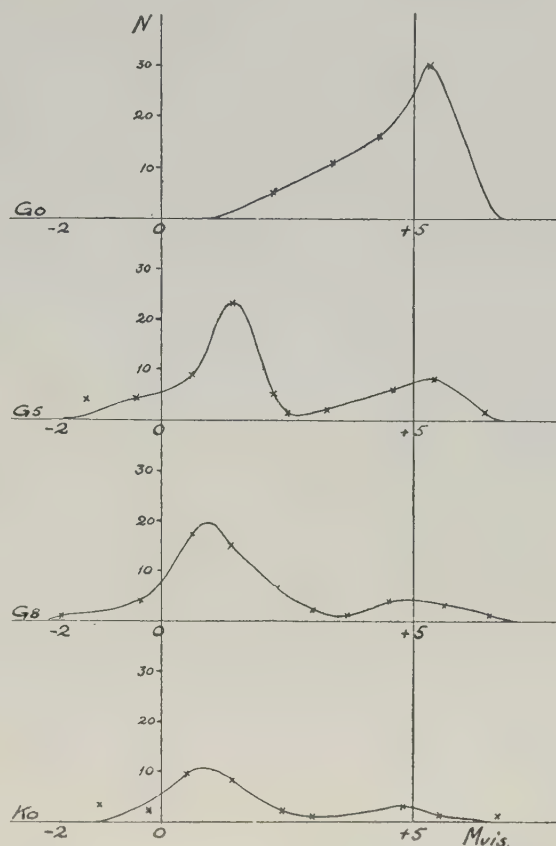


Fig. 6. Distribution of visual absolute magnitudes derived from the cyanogen criterion.

¹ Loc. cit., p. 13.

are found in the general catalogue 174 are dwarfs and only 8 giants. In G5, on the other hand, the giants are in majority. The difference in the distribution of absolute magnitudes in these neighbouring spectral types is very marked.

CHAPTER V.

Effective wave-lengths determined at Greenwich.

1. The method of using the effective wave-length as a colour-equivalent was introduced in 1908 by HERTZSPRUNG¹ and BERGSTRAND.² It has been developed further and used by them in several subsequent investigations.³ Later on it was discussed in detail by LINDBLAD.⁴ Other investigators who have used the method are for instance WOLF, LUNDMARK, ROSENBERG, BALANOWSKY, KREIKEN, and the present writer.

At Greenwich the method was introduced in 1920 for the determination of the colours of stars in the Astrographic catalogue. The instrument used was the 30-inch reflector, focal length 3476 mm. In front of the object glass was placed a grating with the grating-constant $c = 1.423$ mm.

Effective wave-lengths have till now been measured at Greenwich for stars situated between the north pole and 80° declination. The total number of stars is 4472, of which 3733 are contained in the Bonn Durchmusterung catalogue. Preliminary results have been published in three papers.^{5,6,7} The catalogue with the individual effective wave-lengths is not yet published, but through the great kindness of Sir FRANK DYSON I have, as already mentioned, had the opportunity of using the wave-lengths before their appearance in print. They are listed in the column " λ_{eff} " of the general catalogue at the end of this paper.

¹ E. HERTZSPRUNG, Sur la dispersion atmosphérique, Bulletin Astronomique, Vol. 25, 1908.

² Ö. BERGSTRAND, Über die Abhängigkeit der atmosphärischen Dispersionswirkungen von den Sterngrößen, Astronomische Nachrichten, 177, 241, 1908.

³ Ö. BERGSTRAND, Recherches sur les couleurs des étoiles fixes, Nova Acta Reg. Soc. Scient. Upsal., Ser. IV, Vol. 2, No. 4, 1909.

E. HERTZSPRUNG, Über die Verwendung photographisch effektive Wellenlängen zur Bestimmung von Farbenäquivalenten, Publ. d. astrophys. Obs. zu Potsdam, Vol. 22, No. 1, 1911.

E. HERTZSPRUNG, Effective wave-lengths of 184 stars in the cluster N. G. C. 1647, Astrophysical Journal, Vol. 42, 92, 1915, Mount Wilson Contr., No. 100.

E. HERTZSPRUNG, Effective wave-lengths of absolutely faint stars, Astrophysical Journal, Vol. 42, 111, 1915, Mount Wilson Contr., No. 101.

⁴ B. LINDBLAD, Die photographisch effektive Wellenlänge als Farbenäquivalent der Sterne, Arkiv f. mat., astr. o. fys., Band 13, No. 26, 1918.

⁵ C. DAVIDSON and E. MARTIN, Effective wave-lengths of stars in relation to spectral type and colour-index, Monthly Notices, Vol. 82, No. 2, 1921.

⁶ C. DAVIDSON and E. MARTIN, Effective wave-length and spectral classification of faint stars. Standards of reference, Monthly Notices, Vol. 84, No. 6, 1924.

⁷ F. DYSON and E. MARTIN, Effective wave-lengths of stars from dec. 80° to the north pole, Monthly Notices, Vol. 86, No. 1, 1925.

The effective wave-lengths which I originally obtained from Greenwich in manuscript and which I have used for my calculations have later on been revised there. This fact was communicated to me but recently through a proof-sheet, which was sent to me from Greenwich. The corrections, however, are small, generally falling below 10 Ångström units. Besides, only a relatively small part of the wave-lengths have been corrected. Most of them are unaltered. The results of the computations which have been made here with the original values of the wave-lengths may therefore be assumed to be very nearly valid also for the revised ones. The differences in the results probably amount to only a few Ångström units. The effective wave-lengths which are listed in the general catalogue are the revised ones.

2. A question of great interest is the relation between effective wave-length and spectral type. It has been subjected to examination by several authors. As a result of their investigations we may say that the relation is not linear, further that it is easily possible by means of effective wave-lengths to distinguish between white and red stars but scarcely between the successive spectral types, and finally that the wave-lengths of stars of types A0—F8 seem to differ only slightly from each other. The statistical data, upon which these conclusions are based, has, however, been relatively scanty. The only exception is the investigation by DYSON and MARTIN cited before. It embraces all those stars between the pole and 80° declination whose effective wave-lengths were measured in Greenwich and whose spectral types are given in the Draper catalogue. The relation between effective wave-length and spectral type found by these investigators is therefore to be considered very reliable. However, I have now still more material than DYSON and MARTIN, owing to the new spectral determinations made by me, which, besides, certainly are more trustworthy than those of the Draper catalogue. It may then be of interest to verify their results and to examine the correctness of the general conclusions drawn about the relation between effective wave-length and spectral type.

The results of my computations are shown in Table VIII, which contains mean effective wave-lengths and the corresponding dispersions σ for different spectral groups and intervals of apparent photographic magnitude. N is the number of stars of a given spectral group. Only those effective wave-lengths which are based on measurements from at least two plates are used in the computations of mean values.

It is evident from the table that for a given spectral group the wave-length varies but little from one interval of magnitude to another. And, in fact, we cannot trace any drift in the wave-length with magnitude. From this we draw the conclusion that *the Greenwich effective wave-lengths as well as the spectral determinations performed by me are reliable also for faint apparent magnitudes.* In this connection it should be noticed that my spectral classification reaches stars of somewhat fainter magnitude than the Greenwich determinations of effective wave-lengths. This is clearly seen from Part II of the general catalogue, which

Table VIII. Mean effective wave-lengths (computed at Upsala) for different spectral groups and intervals of magnitude.

m Group	< 8.0			8.0—8.9			9.0—9.9			10.0—10.9			≥ 11.0			All stars		
	N	λ_{eff}	σ	N	λ_{eff}	σ	N	λ_{eff}	σ	N	λ_{eff}	σ	N	λ_{eff}	σ	N	λ_{eff}	σ
A0 σ	1	4189														1	4189	
A0 σ —	2	4242		1	4277		1	4226								4	4247	± 25
A0 ρ	4	4246	± 22				1	4169		1	4215					6	4228	34
A0 μ	5	4248	17	3	4247	± 13	6	4242	± 17	1	4232					15	4244	14
A0 κ —	3	4255	2	2	4260		4	4254	14	1	4228					10	4253	13
A0 κ	3	4250	7	4	4262	13	8	4269	14	14	4273	± 28				29	4268	23
A2 μ				2	4254											2	4254	
A2 κ —	7	4270	8	4	4261	9	1	4271								12	4267	9
A2 κ	3	4266	6	8	4266	14	5	4272	13	9	4268	11				25	4268	12
A3 κ —				1	4263											1	4263	
A3 κ	1	4272		1	4262		5	4267	15							7	4267	13
A5	3	4278	9	12	4268		14	4270	15	3	4280	21				32	4271	14
F0	7	4279	15	4	4270	7	8	4266	14	12	4279	19				31	4275	17
F2	4	4281	14	18	4276	13	23	4270	16	33	4274	16	1	(4238)		79	4273	16
F5	8	4289	17	17	4283	20	60	4278	16	79	4278	21	5	4295	± 12	169	4279	19
F8	4	4301	28	12	4301	19	63	4303	25	113	4300	25	12	4297	27	204	4301	25
dG0	3	4339	4	9	4316	25	15	4335	20	63	4330	24	6	4330	15	96	4330	22
dG5	1	4369		3	4382	34	8	4367	19	22	4371	18	2	4392		36	4372	21
dG8							10	4401	22	7	4413	21	1	4466		18	4409	26
dK0				3	4405	17				10	4431	25	1	4430		14	4425	25
dK2							3	4462	9							3	4462	9
gG5	1	4406		11	4413	21	19	4422	14	31	4427	24	3	4396	21	65	4422	22
gG8	1	4436		11	4437	22	32	4448	30	42	4459	15	10	4452	26	96	4452	25
gK0	4	4495	33	5	4466	18	15	4477	23	33	4477	19	6	4457	25	63	4475	23
gK2	4	4527	29	2	4531		8	4513	22	16	4512	19				30	4515	22
gK5	1	4561		2	4554		8	4551	21	10	4549	17	4	4576	23	25	4555	21
gM	2	4544		1	4532		5	4550	21	2	4546					10	4546	19
gMb				1	4431											1	4431	

contains a great many faint stars with estimated spectral types but unknown effective wave-lengths.

If all stars of a certain spectral group in Table VIII are brought together, and the dispersions and means of the effective wave-lengths are computed, the three last columns of the table are obtained. It is of interest to see how closely the values of the column λ_{eff} agree with the corresponding ones computed at Greenwich. The latter are listed in Table IX. They are taken from the proof-

Table IX. Mean effective wave-lengths (computed at Greenwich) for different spectral groups.

Spectrum	λ_{eff}	N	Mean discordance	σ (comp.)	Spectrum	λ_{eff}	N	Mean discordance	σ (comp.)
Oe5	4074	1			F2	4272	32	± 13	± 16
B	4167	1			F5	4279	59	11	14
B2	4148	2			F8	4292	62	19	24
B3	4153	5			G0	4315	59	29	36
B5	4174	4			G5	4401	114	39	49
B8	4219	5	± 33	± 41	K0	4461	163	45	55
B9	4227	13	20	25	K2	4501	38	35	44
A0	4252	95	14	18	K3	4531	1		
A2	4265	57	11	14	K5	4539	15	28	35
A3	4268	26	10	13	Ma	4539	12	14	18
A5	4269	32	11	14	Mb	4488	6	40	50
F0	4270	60	11	17	N	4572	1		
					R3	4591	1		

sheet mentioned above. The spectral types of the table are according to Harvard. Comparing Tables VIII and IX we establish that the Greenwich values for types A5—F5 are nearly identical with mine. For F8 my value is slightly higher (9 Ångström). For stars of type G0 and later I have distinguished in my table between giants and dwarfs and have given the wave-lengths separately for the two groups of stars. In the Greenwich table this is not the case, as the Draper catalogue, as is well known, does not give giants and dwarfs separated. The Greenwich values are thus means for stars with high and low luminosity taken together. My values differ a little from those found in Greenwich, the values for the giants being somewhat greater and those for the dwarfs somewhat smaller than the Greenwich ones. However, if we compute the means within each spectral type we obtain nearly the values found at Greenwich. For the dwarfs of G0-type I find a value of the effective wave-length which is 15 Ångström higher than the Greenwich value for type G0. The values are comparable, as the latter rests on data which with all certainty must have been composed of dwarf stars. Thus for this spectral type a slight difference exists between my computations and those performed at Greenwich. The same is the case for type K5. The Greenwich value for this type is surely almost exclusively based on data of giant stars, owing to the fact that we have not penetrated to such a faint magnitude that the dwarfs of type K5 occur in any noteworthy degree. The difference between my value of the effective wave-length for group gK5 and that of Greenwich for type K5 is 16 Ångström, my value being the higher one.

In Figure 7 a diagram is given, showing the relation between spectral type and

effective wave-length according to Table VIII. It appears from the figure that *the dwarf-branch lies about 50 Ångström below the giant-branch*. LINDBLAD obtained about the same result in his investigation of effective wave-lengths cited before. For the giants of types K5 and M the effective wave-lengths have nearly equal values, and the curve tends to turn downwards, a fact which is indicated also in a diagram by DAVIDSON and MARTIN.¹ For dwarfs later than type K2 no measurements of effective wave-lengths exist in the material here available, and consequently nothing can be said about the course of the dwarf-branch for these types.

The stars of types A0—A3 of Table VIII have been divided into two groups, the first with sharp hydrogen lines and the other with winged ones, and mean effective wave-lengths within each type and group were computed. The result is shown in Figure 7, where the $\varrho-\kappa$ stars are those with winged lines. It is evident from the diagram that the stars with sharp lines, σ , $\sigma-$, have a lower effective wave-length than the $\varrho-\kappa$ stars. The former are bluer and remind one of B stars. They are also intrinsically brighter, as is seen from Table VII. Unfortunately I have no stars of type B in the region examined, and I am unable therefore to determine the course of the curve for types earlier than A0. The absence of B stars is due to the fact that the region is situated relatively far from the galactic plane.

It may be of interest to compare the diagram Figure 7 with BOTTLINGER's² diagram for photo-electric colour-indices in relation to spectral type. We note at once the almost perfect agreement between the diagrams.

It is most remarkable that the effective wave-length changes so little between A0 and F8. If A-type stars with sharp hydrogen lines are excluded we may say that *the effective wave-length is constant from A2 to F5*, and it is evident that we cannot by this colour-equivalent distinguish between the different spectral types within this interval. The A-type stars with winged lines are, in fact, of a rather advanced colour, and are probably to be considered as early F stars.

As a rule the conclusion that the effective wave-length is of no service in separating stars of types A2 to F5 is valid. Under certain circumstances, however, we can very well use the effective wave-length for this purpose. DYSON³ and MARTIN have shown that, by using Ilford Panchromatic plates and a screen which absorbs the blue light, it is possible to obtain a very sensitive relationship between effective wave-length and spectral type also for the interval A2—F5. And, in fact, by this means we get an approximately linear relation over the whole range B8 to M. However, the method has a disadvantage inasmuch as the exposure-times required are considerably increased.

DYSON has also made a comparison (according to the proof-sheet mentioned before) of effective wave-length with spectral type for stars with known parallaxes

¹ Monthly Notices, Vol. 82, No. 2, 1921, p. 75.

² K. F. BOTTLINGER, *Lichtelektrische Farbenindizes von 459 Sternen*, Veröffentlichungen der Universitätssternwarte zu Berlin-Babelsberg, III, Heft 4, 1923, Tafel I.

³ Loc. cit., p. 30.

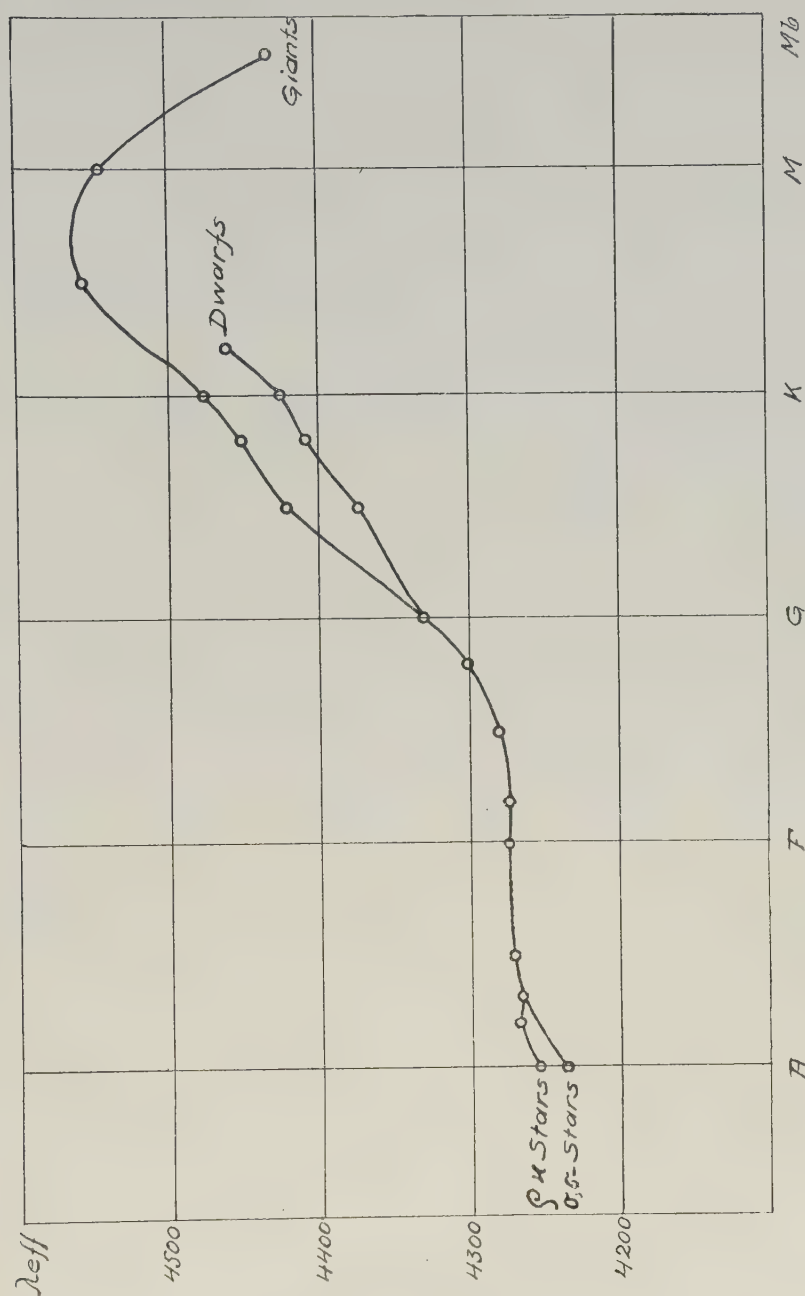


Fig. 7. Relation between effective wave-length and spectral type (Upsala).

in order to determine whether effective wave-length renders it possible to discriminate between giants and dwarfs of the same spectral type. He gives a list of stars which contains among other data the absolute magnitude and the difference between the mean effective wave-length for a given spectral type and the wave-

length of a particular star. DYSON draws the conclusion from his list that "in all cases where the effective wave-length is greater than the average for that spectral class, the star is one of great luminosity and in the contrary case one of small luminosity". I have compared the absolute magnitudes of the stars in DYSON's list with the magnitudes deduced by me for the same stars. If the latter are assumed to be more reliable I find that DYSON's conclusion holds in ten of the examined twelve cases. It may thus be said to be very well substantiated. *When the spectral type of a star is accurately known it is accordingly possible from the method of effective wave-lengths to discriminate between giant and dwarf character.* This has previously been pointed out by LINDBLAD.¹

We now return to Tables VIII and IX in order to examine the distribution of effective wave-lengths about the means. The Greenwich computers have not given the dispersions σ but only mean discordances. Approximate values of the former were therefore computed by me by multiplying the mean discordances by 1.2533. They are listed in the columns headed " σ (comp.)". If we compare the dispersions σ of the effective wave-lengths according to my computations and according to those made at Greenwich we find that they agree very well for types A0—F8. For types G0—M, however, the Greenwich values are considerably greater than mine. This is surely to a great extent due to the fact that the Harvard classification does not distinguish between giants and dwarfs. But probably part of it must be accounted for on the assumption that the Harvard classification is not quite so reliable as that of Upsala. — As a general impression it may be said that the Greenwich effective wave-lengths seem to be very good.

The effective wave-lengths here treated are, as mentioned before, based on measurements made on at least two plates. For very faint stars, however, the wave-lengths determined at Greenwich rest on only one plate. I have computed mean effective wave-lengths and dispersions for such stars, too, in all 171. These means do not differ much from those based on more plates. The difference amounts in general to ten or twenty Ångström units. The dispersions are naturally rather great. But as a rule they fall below 35 Ångström.

3. It was previously mentioned that the logarithmic exposure-ratio $\log E_G$ has the character of a colour-equivalent. This has been proved by LINDBLAD by comparing the relation between $\log E_G$ and spectral type with other results expressing the dependence of colour on spectral type. Thus he found that $\log E_G$ and λ_{eff} behave in practically the same way when plotted against spectral type. Accordingly it may be expected that there exists a close correlation between these colour-equivalents. In order to examine the correlation I have in Figure 8 plotted λ_{eff} against $\log E_G$. The diagram contains all stars with measured λ_{eff} and $\log E_G$ within the spectral range F8—M. The whole number of stars is 355. Black dots denote F8 stars, crosses dwarfs and circles giants of types G0—M. It appears at a glance on the diagram that the correlation must be very great. The dispersion is remarkably small.

¹ Arkiv f. mat., astr. o. fys., Band 13, No. 26, 1918.

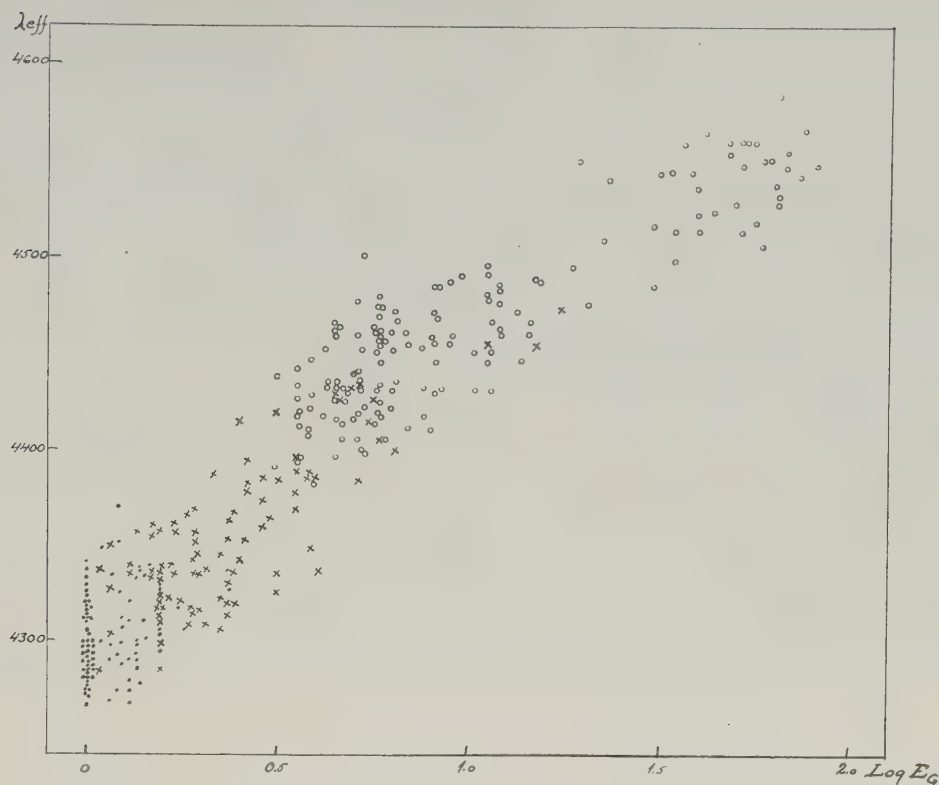


Fig. 8. Effective wave-length as a function of $\log E_G$. • F8 stars. × Dwarfs of types G0—M.
○ Giants of types G0—M.

If mean effective wave-length and $\log E_G$ are computed separately for giants and dwarfs of successive spectral types the values of Table X are obtained. N is the number of stars. The result is also shown in Figure 9, where the upper curve refers to the giants and the lower one to the dwarfs. As is apparent they do not

Table X. Effective wave-length and colour-equivalent $\log E_G$ for different spectral groups.

Spectrum	N	λ_{eff}	$\log E_G$	Spectrum	N	λ_{eff}	$\log E_G$
F8	98	4303	0.06	gG5	45	4423	0.62
dG0	56	4331	0.24	gG8	52	4448	0.82
dG5	19	4371	0.45	gK0	26	4480	1.07
dG8	10	4405	0.62	gK2	14	4519	1.53
dK0	5	4409	0.74	gK5	15	4552	1.76
dK2	3	4462	1.16	gM	9	4528	1.63

deviate far from linearity. The upper curve lies about 20 Ångström higher than the lower one.

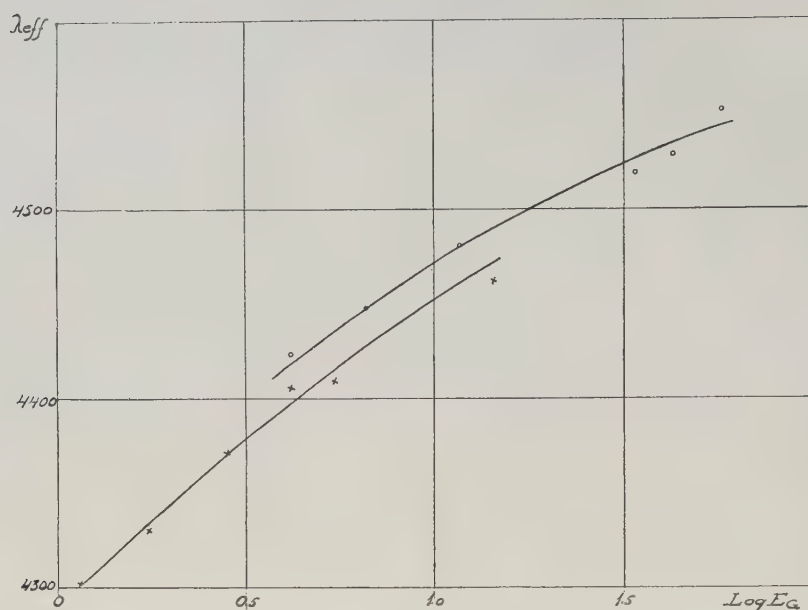


Fig. 9. Relation between effective wave-length and $\log E_G$. (The upper curve refers to giant stars, the lower one to dwarfs.)

Let us finally compute the correlation coefficient. If we do not distinguish between giants and dwarfs we obtain the correlation given in Table XI. From this we deduce the correlation coefficient 0.920 with a mean error equal to ± 0.008 . It is consequently obvious that $\log E_G$ and λ_{eff} are nearly identical in character.

Table XI. The correlation between effective wave-length and colour-equivalent $\log E_G$.

$\log E_G$ λ_{eff}	0.0—0.2	0.2—0.4	0.4—0.6	0.6—0.8	0.8—1.0	1.0—1.2	1.2—1.4	1.4—1.6	1.6—1.8	1.8—2.0	$\Sigma \lambda$
4260—4290	32										32
4290—4320	49	13									62
4320—4350	32	14	4	1	1						52
4350—4380	6	9	10								25
4380—4410		2	11	9	1						23
4410—4440			13	28	10	2					53
4440—4470			2	19	12	11	1				45
4470—4500				5	7	10	3	2			27
4500—4530				1	1		1	2	7	1	13
4530—4560							1	3	5	6	15
4560—4590								1	5	2	8
ΣG	119	38	40	63	32	23	6	8	17	9	355

CHAPTER VI.

The distribution of tangential velocities of stars in the Carrington zone.

1. The tangential velocities are easily obtained from the proper motions when the distances of the stars are known. The proper motions of the stars here in question are published in the Greenwich Astrographic catalogue, Vol. IV. The distances have, as already mentioned, been deduced by me.

The determination of velocities have been performed in the following way. The components of proper motions, μ_α and μ_δ , were reduced to photographic magnitude 8.0 (on the International scale) by multiplication with a factor

$$f = 10^{\frac{1}{5}(m - 8.0)}$$

Then the components of reduced proper motions, μ'_α and μ'_δ , were converted into the system of *galactic longitude and latitude*, μ_L and μ_B , according to the formulae

$$\begin{cases} \mu_L = \mu_\alpha \cos \psi - \mu_\delta \sin \psi \\ \mu_B = \mu_\alpha \sin \psi + \mu_\delta \cos \psi \end{cases} \quad \begin{cases} \cos B \sin \psi = \cos D \sin (A - \alpha) \\ \cos B \cos \psi = \sin D \cos \delta - \cos D \sin \delta \cos (A - \alpha) \end{cases}$$

ψ is the angle between the great circles through a given star and the celestial and galactic north pole respectively, α and δ are the right ascension and declination of the star, A and D the right ascension and declination of the galactic north pole. I have assumed $A = 190^\circ.6$ and $D = +27^\circ.2$. In order to facilitate the computations tables were constructed giving $\sin \psi$ and $\cos \psi$ as functions of α for different values of δ . Finally the linear velocities V_L and V_B in km per sec were obtained by multiplying μ_L and μ_B by a factor k , which is given by

$$k = \frac{K}{N} 10^{-\frac{1}{5}(M_{ph} - 5 - 8.0)}$$

Here K is the semi-axis of the earth's orbit in km, N the number of seconds in a year, and M_{ph} the absolute photographic magnitude. We get

$$\log k = 3.2756 - \frac{1}{5} M_{ph}$$

Velocities were computed not only for stars with estimated absolute magnitudes, but also for stars for which only a spectral classification was available. The

values of the absolute magnitudes adopted in the latter case are those given in Table VI.

The absolute magnitude for stars of type A5 and later requires a small positive correction when deriving the most probable velocity. If we assume the errors in the absolute magnitude to be distributed in a normal error curve with dispersion ε we get the following expression^{1,2} for the correction: $2.5 (0.46)^2 \varepsilon^2 \log e$. Assuming now the mean error to be $\varepsilon = 1.0$ the correction becomes 0.2. This quantity is thus to be added to the adopted absolute magnitudes when computing the velocities. The correction has been applied, too, in the computation of distances. For stars of types A0–A3 the error ε is probably so small that the correction will be without significance.

Before using the velocities for calculations it is necessary to determine whether they are affected by systematic errors. The velocities are gathered from four different regions, and we may suppose that this fact should in the general mean counteract errors of the mentioned kind. In order to trace a potential error I have computed mean velocities for each region separately and compared them with each other. The manner of proceeding was the following one: The stars were divided into two catalogues, the one for stars with apparent visual magnitude $m_{vis} < 9.5$ and the other with $m_{vis} > 9.5$. That the visual magnitude is used as a basis of classification is due to the fact that the Greenwich proper motions are obtained from meridian observations. For each catalogue means of m_{vis} , $\bar{V}_L$, and $\bar{V}_B$ were computed for the different regions and spectral types. In this way $\bar{V}_L$ and $\bar{V}_B$ for twelve spectral groups were obtained for each region and catalogue.

Table XII. Mean tangential velocities for different celestial regions and apparent visual magnitudes.

0h				6h				12h				18h			
$\bar{m}_{vis}$	$\bar{V}_L$	$\bar{V}_B$	N	$\bar{m}_{vis}$	$\bar{V}_L$	$\bar{V}_B$	N	$\bar{m}_{vis}$	$\bar{V}_L$	$\bar{V}_B$	N	$\bar{m}_{vis}$	$\bar{V}_L$	$\bar{V}_B$	N
8.5	+12.9	−2.0	166	8.6	+10.3	−5.0	133	8.5	+9.9	−5.2	118	8.4	+10.0	−9.0	105
10.1	+ 8.0	−6.4	149	10.1	+ 5.9	−2.5	152	10.1	+6.3	−5.5	149	10.3	+11.8	−6.8	181

When comparing $\bar{V}_L$ and $\bar{V}_B$ no decided drift with the position of the region was detectable. Nor was a systematic difference in size between the velocities of the brighter and of the fainter stars evident. The number of stars of each spectral group is, however, relatively small and accordingly the estimate a little uncertain. In order to obtain a more reliable one I have treated all stars of a given region

¹ B. LINDBLAD, Spectrophotometric determinations etc., p. 51.

² B. LINDBLAD, Researches based on etc., p. 16.

together. Table XII gives the result. The four regions are denoted by 0^h , 6^h , 12^h , and 18^h respectively. N is the number of stars used. Nor in this case can a drift in the velocity with the position of the region with certainty be established. The values of $\bar{V}_B$ for the brighter stars possibly indicate such a drift, but for the fainter stars it cannot be detected. The values of $\bar{V}_L$ show no systematic variation with the position of the region. On account of the impossibility of saying anything with assurance about the possible systematic errors, these have been neglected.

Finally we have to regard accidental errors in the proper motions. When converting the proper motions to linear velocities we have first, as quoted before, reduced them to an apparent photographic magnitude of 8.0. Then we have multiplied with the factor k . As k is greater the smaller M_{ph} is, we see that k becomes comparatively great for the A stars and the giants of late types. A given error in the proper motion produces accordingly for such stars a greater error in the absolute velocity than for stars of other spectral groups. The probable numerical amounts of the accidental errors will be given later.

2. The velocities have been used for computation of velocity-ellipses. Only such velocities were adopted for which the product of k and the factor used for reducing the proper motions to $8^m.0$ falls below or is equal to 2000. This means in other words that the velocity-ellipses are based on stars with inferred distances which do not exceed 417 parsecs. Velocities belonging to stars remoter than this distance are probably too uncertain and have been treated separately. For them only $\bar{V}_L$ and $\bar{V}_B$ were computed, not the higher characteristics of the velocity-ellipse.

The velocities of individual stars are not given in the general catalogue. This is naturally a shortcoming but is explained partly through lack of space and partly on account of the uncertainties of the velocities produced by errors in the proper motions and in the spectrophotometric determinations of absolute magnitudes. The computed velocities, which are to be considered individually rather unreliable, are probably suitable only for statistical treatment. Because of this their omission from the general catalogue might be said to be justified.

The individual velocities are, however, illustrated in the velocity diagrams, which will now be discussed. Figures 10–17 show the diagrams for different spectral groups. The origin of a diagram represents the velocity of the sun, the distance from the origin to a point in the diagram the tangential velocity in km per sec of an individual star relative to the sun. Accordingly if we suppose that all stars of a given group start from the origin at the same moment with velocities equal and parallel to their tangential velocities the stars will after one second be spread out in a cluster, in conformity to the diagrams given here. The distribution of the stars in these clusters will presently be subjected to treatment.

The data given in the diagrams are gathered from four regions, as quoted before, and they are assumed to be valid for the centre of the investigated tract, *viz.* the celestial north pole. On account of the proximity of the regions this must be considered very nearly correct. The galactic coordinates of the pole are $L = 90^\circ$,

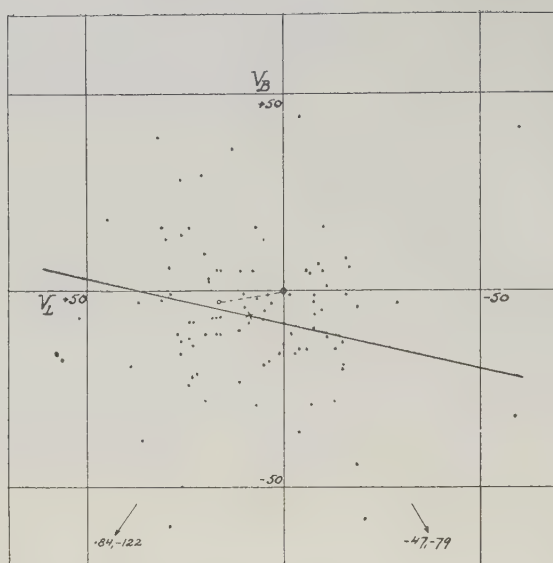


Fig. 10. Velocity diagram for types A0—A3.

$B = +27^\circ$. The positive axes of V_L and V_B are directed towards increasing galactic longitude and latitude. The full-drawn lines signify the major axis of the velocity-

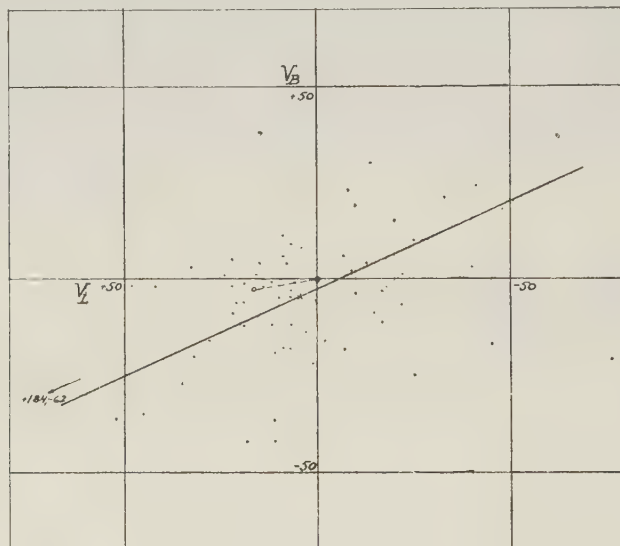


Fig. 11. Velocity diagram for types A5—F0.

ellipses, the constants of which will be computed later. The cross is the centre of the ellipse. The dotted line indicates the projection of velocity from the sun to the ordinary centroid of apparently bright stars. With a solar motion amounting

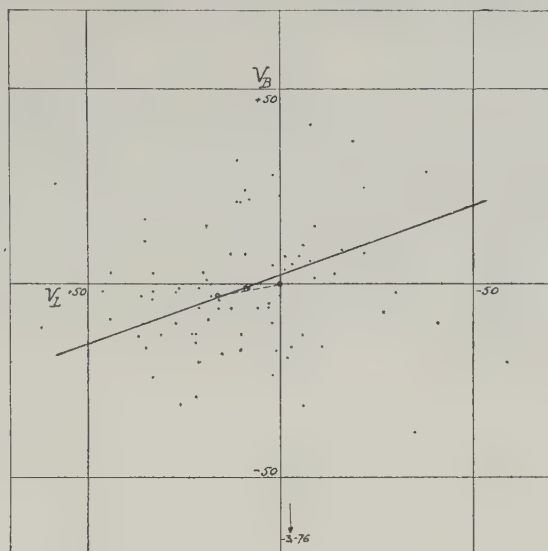


Fig. 12. Velocity diagram for type F2.

to 19.5 km per sec towards apex R. A. 270° , Dec. $+30^\circ$ we get the position of the centroid $V_L = +16.6$, $V_B = -2.9$ in the present diagrams.

For the spectral groups A5–F8 we have adopted rather arbitrary mean abso-

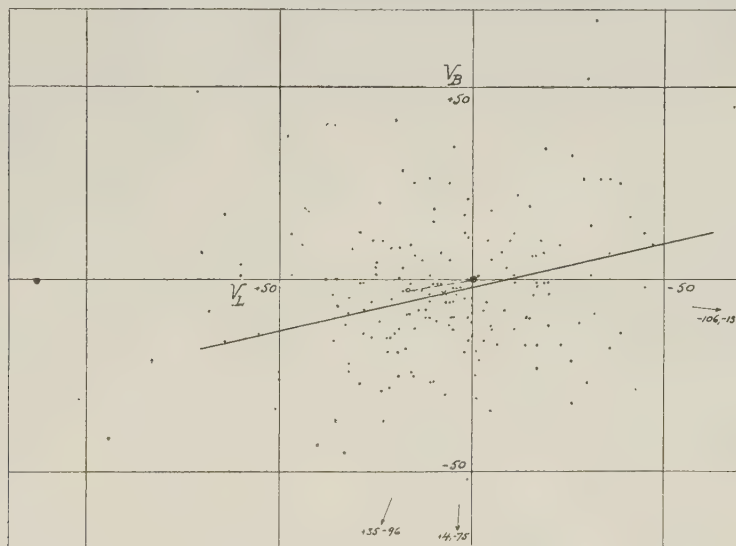


Fig. 13. Velocity diagram for type F5.

lute magnitudes when computing velocities and distances. The inferred velocities of these groups involve therefore errors which are not only due to the dispersion in the absolute magnitude and to errors in the proper motions but also to wrong

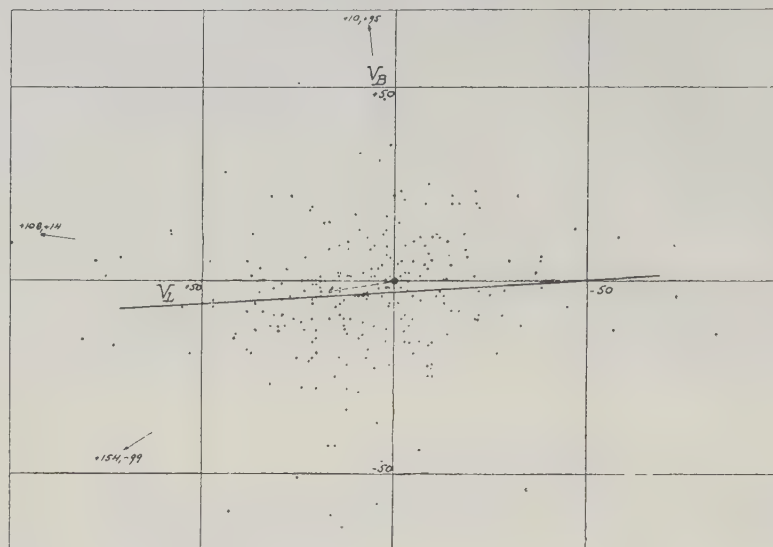


Fig. 14. Velocity diagram for type F8.

assumptions as to the values of the mean magnitude. The dispersions of the velocity diagrams may, in fact, give us an idea of the propriety of our assumptions.

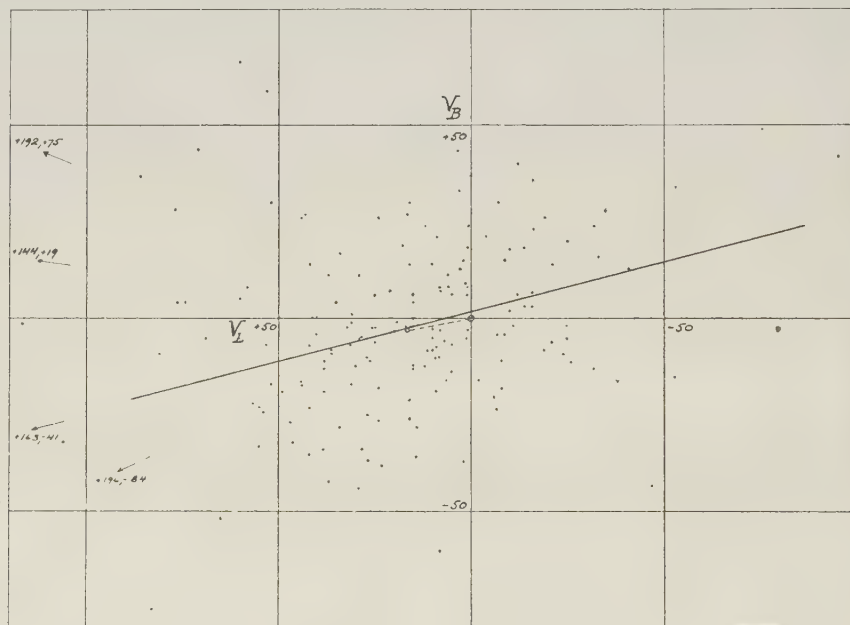
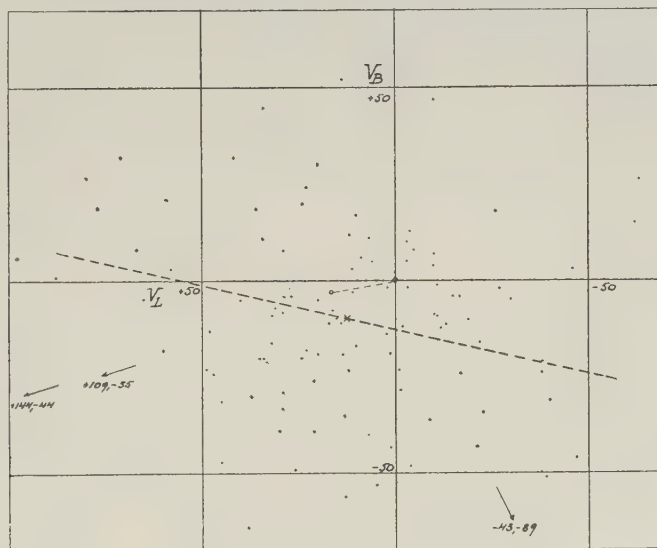


Fig. 15. Velocity diagram for dwarfs of types G0—G5.

We conclude from the diagrams given here that the adopted mean magnitudes cannot be far wrong.

Fig. 16. Velocity diagram for *dwarfs* of types G8—K2.

3. Let us now compute the characteristics of the velocity-ellipses of different spectral groups. As quoted above *only such velocities have been used which belong to stars within 417 parsecs from the sun.* And further, those velocities

Fig. 17. Velocity diagram for *giants* of types G5—K2.

were excluded which in any component exceeded 70 km relative to the "standard" centroid, *i. e.* approximately with $V_L - 20$ or V_B exceeding 70 km. Higher velocities if included in the calculations of mean velocities and moments would displace the

results to a considerable degree. We obtain easily the mean motion $\bar{V}_L$, $\bar{V}_B$ and then determine the other constants of the velocity-ellipses from the moments of second order about $\bar{V}_L$ and $\bar{V}_B$ according to CHARLIER's formulae¹:

$$f = \frac{x^2}{\left(\sqrt{\frac{1}{A_0}}\right)^2} + \frac{y^2}{\left(\sqrt{\frac{1}{B_0}}\right)^2}, \quad \begin{cases} 2A_0 = A_1 + B_1 + \frac{A_1 - B_1}{\cos 2\varphi}, \\ 2B_0 = A_1 + B_1 - \frac{A_1 - B_1}{\cos 2\varphi} \end{cases} \quad \begin{cases} A_1 = \frac{1}{(1-r^2) N_{20}} \\ B_1 = \frac{1}{(1-r^2) N_{02}} \end{cases}$$

$$r^2 = \frac{N_{11}^2}{N_{02} \cdot N_{20}}, \quad \operatorname{tg} 2\varphi = \frac{2N_{11}}{N_{20} - N_{02}}$$

$$N_{20} = \frac{\Sigma (V_L - \bar{V}_L)^2}{n}, \quad N_{02} = \frac{\Sigma (V_B - \bar{V}_B)^2}{n}, \quad N_{11} = \frac{\Sigma [(V_L - \bar{V}_L)(V_B - \bar{V}_B)]}{n}$$

In Table XIII $\bar{V}_L$, $\bar{V}_B$, $\sqrt{\bar{V}_L^2 + \bar{V}_B^2}$, and the computed moments are given. n is the number of stars in a given group.

Table XIII. Computed moments for spectral groups.

Group	n	$\bar{V}_L$ km	$\bar{V}_B$ km	$\sqrt{\bar{V}_L^2 + \bar{V}_B^2}$ km	N_{20}	N_{02}	N_{11}
A0—A3	96	+ 8.9	—6.2	10.9	510	342	+ 18
A5—F0	66	+ 4.7	—4.5	6.5	533	270	—148
F2	81	+ 9.4	—0.7	9.4	469	257	— 89
F5	187	+ 7.1	—3.7	8.0	573	276	— 73
F8	243	+ 7.3	—3.2	8.0	493	259	— 14
dG0—G5	160	+15.9	—1.9	16.0	722	437	— 81
dG8—K2	43	+13.3	—4.5	14.0	790	144	— 85
gG5—K2	100	+12.4	—9.8	15.8	732	520	+ 95

Before advancing further in the calculations the moments of Table XIII must be corrected, as they include effects arising from accidental errors in the proper motions. According to LINDBLAD² we assume that the mean error in one coordinate amounts to 0".013. The effect of this error will not be the same for the different spectral groups, as mentioned before, on account of their different mean distances. We estimate the effect in the following way. For each spectral group we determine a limit of distance d , so defined that beyond d the thinning out of stars is clearly perceptible. We make the assumption that the errors in the proper motions are valid for 0.7 of this distance. Then we obtain the following numerical values of the mean error in the linear velocities

¹ C. V. L. CHARLIER, Studies in stellar statistics, Lund Meddelanden, Ser. II, No. 9, 1912.

² B. LINDBLAD, Researches based on etc., p. 19.

Group	A0—A3	A5—F0	F2	F5	F8	dG0—K2	gG5—K2
Mean error in km. . . .	13.6	12.4	12.4	9.4	7.5	6.2	17.2

These values deviate very little from those found by LINDBLAD in his "Second paper". We get the true values of the moments by subtracting the squares of the errors just computed from N_{20} and N_{02} in Table XIII. The values which we obtain with these moments for the semi-axes of the velocity-ellipses or, in other words, the greatest and the smallest dispersion in the velocities, must, however, be corrected somewhat in order to give the true dispersions. The cause for this are the accidental errors in the absolute magnitudes, which produce a correction factor equal to the square of the corresponding factor for the mean velocity. A more detailed treatment of the matter is given by LINDBLAD in his "First paper". The correction factor with which the dispersions are to be multiplied is equal to 0.90 for all spectral groups except A0—A3, for which it is neglected. We obtain finally the characteristics of the velocity-ellipses which are listed in Table XIV. σ_1 , σ_2 are the dispersions along the principal axes of the ellipse, φ is the angle between the major axis and the V_L -direction, counted positively towards V_B , and L_0 the galactic longitude for the intersection between the φ -direction and the galactic plane.

Table XIV. Constants of velocity-ellipses.

Group	σ_1 km	σ_2 km	σ_2/σ_1	φ	L_0
A0—A3	20.4	16.6	0.81	+ 6° 3'	193°
A5—F0	19.0	6.3	0.33	—24° 11'	136°
F2	16.8	7.6	0.45	—20° 1'	142°
F5	14.5	11.8	0.81	—13° 5'	154°
F8	18.8	12.8	0.68	— 3° 26'	173°
dG0—G5	23.9	17.5	0.73	—14° 48'	151°
dG8—K2	24.9	8.8	0.35	— 7° 22'	165°
gG5—K2	19.6	12.3	0.63	+20° 56'	219°

4. It appears from the values of σ_2/σ_1 in Table XIV that the velocities, as a rule, show a pronounced ellipsoidal distribution. For the groups A0—A3 and F5, however, the ellipsoidal character is less decided. The direction of the major axis is approximately the same for the groups A5—F8 and dG0—K2. For A0—A3, on the contrary, it shows a considerable deviation. The same is the case for gG5—K2, a result probably not accordant with the real states. The discordance might be accidental. For this reason the major axis in the diagram Figure 17 is dotted.

If the velocity-ellipsoids are supposed to be prolate ellipsoids of revolution we may obtain the vertex of the stellar motions, if we determine the intersection between the great circles defined by the computed φ -directions for the region here investigated and for that of LINDBLAD ($L = 103^\circ$, $B = +46^\circ$). We calculate a weighted

mean of φ for each region taking together all star groups and then find the true *mean vertex* $L=162^\circ$, $B=+3^\circ$ or in equatorial coordinates $\alpha=94^\circ$, $\delta=+17^\circ$. As a comparison we may cite a vertex value obtained by LINDBLAD with the help of data from his above-mentioned region and another region ($L=84^\circ.5$, $B=+14^\circ$) studied by him in his "First paper". He found the mean vertex for stars of types A5—K2, $L=149^\circ$, $B=+11^\circ$ or in equatorial coordinates $\alpha=96^\circ.5$ $\delta=+33^\circ$.

According to WICKSELL¹ we are able to compute the characteristics of the velocity-ellipsoid of a group of stars, if we know the velocity-ellipses of two celestial regions. This condition is fulfilled here. However, my region and those of LINDBLAD are situated so near to each other that the method is not likely to be applied with success. Accordingly I have resigned a rigorous computation of the ellipsoid. For the same reason I have thought it meaningless to deduce apex and solar motion from data for the regions in question. However, we are able to get an approximate determination of the constants of the velocity-ellipsoid by assuming it to be an ellipsoid of revolution. We first compute the dispersions of the velocity-ellipse which represents the motions of all stars of the examined region and find $\sigma_1=19.4$ km per sec, $\sigma_2=13.1$ km per sec. The angle χ between the vertex and the centre of the velocity-ellipse is $66^\circ.5$. With the help of these values we obtain for the major axis of the ellipsoid $\sigma_I=19.9$ km per sec. Accordingly we have the following *approximate data for the velocity-ellipsoid*:

$$\begin{cases} \sigma_I = 19.9 \text{ km per sec} \\ \sigma_{II} = \sigma_{III} = 13.1 \text{ km per sec} \end{cases}$$

The one *direction of the major axis* is, as mentioned before, $L=162^\circ$, $B=+3^\circ$ and thus the opposite one

$$L_I = 342^\circ, B_I = -3^\circ$$

CHARLIER² gives the following values of the axes of the velocity-ellipsoid, the values being computed from radial velocities of 1986 stars:

$$\begin{cases} \sigma_I = 19.54 \text{ km per sec} \\ \sigma_{II} = 13.43 \text{ km per sec} \\ \sigma_{III} = 15.61 \text{ km per sec} \end{cases}$$

The direction of the axes are according to CHARLIER:

¹ S. D. WICKSELL, The general characteristics of the frequency function of stellar movements as derived from the proper motions of the stars, Lund Meddelanden, Ser. II, No. 12, 1915.

² C. V. L. CHARLIER, The motion and the distribution of the stars, Memoirs of the University of California, Vol. 7, 1926.

$$\begin{cases} L_I = 341^\circ.20, & B_I = -5^\circ.71 \\ L_{II} = 69^\circ.58, & B_{II} = -16^\circ.17 \\ L_{III} = 270^\circ.00, & B_{III} = +72^\circ.77 \end{cases}$$

From the above it will be seen that my values of σ_I and σ_{II} agree almost completely with those of CHARLIER. The direction obtained for the major axis of the ellipsoid is nearly identical, too, in both computations. From this we conclude that *the absolute magnitudes used by me for calculation of linear velocities must be nearly correct*. This statement is important for the following discussion of the parallactic motion.

The velocity-ellipsoid of LINDBLAD's region ($L = 103^\circ$, $B = +46^\circ$) was determined in the same way as for my region. The axes are the following:

$$\begin{cases} \sigma_I = 21.2 \text{ km per sec} \\ \sigma_{II} = \sigma_{III} = 11.0 \text{ km per sec} \end{cases}$$

Also these values agree rather well with those given by CHARLIER.

For the ratio between one of the equal minor axes and the major axis of the ellipsoid of my region I find

$$\frac{\sigma_{II}}{\sigma_I} = 0.66,$$

a result being in good harmony with other calculations concerning this matter. In this connection it may be mentioned that LINDBLAD¹, starting from a new theory of the structure of the universe to be dealt with more closely in the following, has found the theoretical value 0.65.

Table XV.

Group	$\bar{V}_L$ km	$\bar{V}_B$ km	$\bar{\sigma}_1$ km	$\bar{\sigma}_2$ km	Galactic drift km
A0—F2	+ 7.1	— 3.7	16.2	8.3	0.0
F5—8	+ 9.0	0.0	19.2	12.0	— 5.3
G0—K2	+ 12.0	+ 3.7	23.5	15.6	— 11.4

5. Now we will proceed to the treatment of $\bar{V}_L$ and $\bar{V}_B$, the speeds relative to the sun of the different groups of stars. LINDBLAD has computed $\bar{V}_L$ and $\bar{V}_B$ for the three groups A0—F2, F5—8, and G0—K2. See Table XV. He found for his region that the centroid is displaced along a straight line nearly at right angles to the vertex direction of the ordinary star-streaming, as the dispersion of the star groups increases. This motion of the centroid is called by LINDBLAD the "galactic drift", and he identifies it with the "asymmetrical drift" previously pointed out

¹ B. LINDBLAD, On the cause of the ellipsoidal distribution of stellar velocities, Arkiv f. mat., astr. o. fys., Band 20 A, No. 17, 1927.

by STRÖMBERG.¹ The direction of the galactic motion is according to LINDBLAD towards $L=77^\circ$. STRÖMBERG² has found $L=61^\circ.5$, $B=+9^\circ.0$ for the direction opposite to that of the asymmetrical drift.

Table XVI.

Group	$\bar{V}_L$ km	$\bar{V}_B$ km	$\bar{\sigma}_1$ km	$\bar{\sigma}_2$ km
A0 - F2	+ 7.9	— 3.9	13.8	10.8
F5—8	+ 7.2	— 3.4	16.9	12.4
G0—K2	+ 14.4	— 4.9	22.6	14.5

An attempt has been made to trace the galactic drift also for the region here examined. For this reason I have computed means of $\bar{V}_L$ and $\bar{V}_B$ for the same groups as LINDBLAD. See Table XVI. It appears from the table that $\bar{V}_L$ and $\bar{V}_B$ of the first group are nearly equal to the corresponding values of the second. Nor do the dispersions differ much from each other. For the third group, on the contrary, the dispersion is somewhat increased and simultaneously the centre of motion considerably displaced. This displacement ought to be the projection of the galactic drift on the region. I have resigned the computation of the direction of the galactic drift on account of the fact that the examined region is situated so near the apex of the asymmetrical drift. The result would become too uncertain as to allow trustworthy conclusions. However, from the values of Table XVI we can set down that the drift takes place roughly in the right direction.

6. If we adopt the solar motion 19.5 km per sec towards apex R. A. 270° , Dec. $+30^\circ$ we find its projection on the examined region to be 16.9 and thus the position of the centroid, as mentioned before, $V_L=+16.6$, $V_B=-2.9$. Comparing now the speed 16.9 with the values of $\sqrt{\bar{V}_L^2 + \bar{V}_B^2}$ in Table XIII we find that the latter are all smaller than 16.9. The deviation is very considerable for stars of types A0—F8. It may be difficult to state with certainty the real interpretation of the phenomenon. We should possibly think it due to errors of considerable amounts in the absolute magnitudes used for computation of the linear velocities. This explanation, however, does not hold, as is evident from the preceding discussion of the velocity-ellipsoid. A possible interpretation of the anomaly is given by a new theory of stellar motions set forth by LINDBLAD³ in a series of papers. We shall briefly draw the outlines of the theory.

¹ G. STRÖMBERG, The asymmetry in stellar motions and the existence of a velocity-restriction in space, *Astrophysical Journal*, Vol. 59, 228, 1924, Mount Wilson Contr., No. 275.

² G. STRÖMBERG, The asymmetry in stellar motions as determined from radial velocities, *Astrophysical Journal*, Vol. 61, 363, 1925, Mount Wilson Contr., No. 293.

³ B. LINDBLAD, Star-streaming and the structure of the stellar system, *Arkiv f. mat., astr. o. fys.*, Band 19 A, No. 21, 1925.

B. LINDBLAD, On the dynamics of the system of globular clusters, *Arkiv f. mat., astr. o. fys.*, Band 19 A, No. 27, 1926.

According to LINDBLAD we assume that the stellar system may be divided in a series of sub-systems, all rotating around a common axis but with different angular speed of rotation. The axis of rotation is assumed to be at right angles to the galactic plane and the direction of the rotation to be retrograde as observed from a point north of the plane. All the sub-systems are thought to have the same extension in the galactic plane. The inner systems have a higher speed of rotation than the outer ones and therefore show a greater flattening. The stars of low velocity observed in our neighbourhood form a sub-system with high speed of rotation, globular clusters form another but one with low angular speed. The centre of the stellar system is supposed to lie in the galactic plane towards longitude $L = 330^\circ$.

The theory has been set forth starting from the asymmetry of the stellar motions. It enables us to explain the character of the systematic motions of stars of high velocity and also the stellar motions in general. The theory has received very strong support in an investigation by OORT¹, in which data evidently confirming LINDBLAD's assumption of a rotation of the galactic system have been given. According to OORT the rotation causes in the stellar velocities an effect of the form

$$rA \sin 2(l-l_0)$$

in radial direction and

$$rA \cos 2(l-l_0) + rB$$

in the transverse direction. Here r is the distance from the sun to a group of stars, l_0 is the galactic longitude of the centre of the stellar system and l the longitude of the group of stars. Further

$$A = \frac{V}{4R} \left(1 - \frac{R}{K} \frac{\partial K}{\partial R} \right)$$

$$B = A - \frac{V}{R}$$

$$V = \sqrt{RK}$$

In these expressions R is the distance to the centre of the stellar system, V the rotational velocity near the sun and K the gravitational force. OORT attempts to substitute the sum of two forces K_1 and K_2 for K . K_1 is supposed to arise from a hypothetical mass in the centre of the system and to vary inversely proportional to the square of R . K_2 is the force from a series of spheroids around the centre. It is supposed to be directly proportional to R . OORT finds

B. LINDBLAD, Cosmogonic consequences of a theory of the stellar system, Arkiv f. mat., astr. o. fys., Band 19 A, No. 35, 1926.

B. LINDBLAD, Star-streaming and the structure of the stellar system (second paper), Arkiv f. mat., astr. o. fys., Band 19 B, No. 7, 1926.

B. LINDBLAD, On the state of motion in the galactic system, Monthly Notices, Vol. 87, No. 7, 1927.

¹ J. H. OORT, Observational evidence confirming Lindblad's hypothesis of a rotation of the galactic system, Bull. Astr. Netherlands, Vol. 3, No. 120, 1927.

$$\frac{K_2}{K_1} = 0.29$$

Using this value and $l = 90^\circ$ (gal. long. of the present region) and OORT's value $l_0 = 325^\circ$ I obtain the following expression for the effect of rotation at right angles to the line of sight:

$$-1.06 rA$$

A is according to OORT equal to 0.0310 ± 0.0037 (m. e.). The proper motions have thus been reduced through the rotation. The amount of the decrease is dependent on the distance of the group of stars from us. If we treat all stars of the region (with known proper motions and at distances < 417 parsecs) as a whole we find their average distance to be about 175 parsecs. If we further account that the distance ought to be counted perpendicularly to the axis of rotation we obtain for the component of velocity $\bar{V}_L$ of the examined region

$$\text{the effect of rotation} = -5.0 \text{ km per sec.}$$

Applying this value to the parallactic motion 16.6 km per sec in galactic longitude for the present region we find that

a parallactic motion of 11.6 km per sec in the direction of V_L is to be supposed.

With the help of Table XIII we now compute a weighted mean of $\bar{V}_L$ for all stars. In this way we find that

$$\text{the really observed parallactic motion in the direction of } V_L \text{ is } 9.8 \text{ km per sec.}$$

The difference between supposed and observed $\bar{V}_L$ is only 1.8 km per sec. We thus get for the supposed parallactic motion $\bar{V}_L = +11.6$, $\bar{V}_B = -2.9$ and really find $\bar{V}_L = +9.8$, $\bar{V}_B = -4.0$. Accordingly it is obvious that OORT's results account very well for the real states of motion.

The effect of rotation is as mentioned above dependent on the distance. Accordingly we should trace a drift in $\bar{V}_L$ in the different groups of stars. However, such a one is scarcely to be proved with the present data and is complicated by the phenomenon of the asymmetrical drift.

7. Finally values of $\bar{V}_L$ and $\bar{V}_B$ for stars at distances > 417 parsecs may be given. They are almost only giants of late types. We obtain for types gG5—K2, $\bar{V}_L = +10.1$, $\bar{V}_B = -12.4$. The number of stars used for the computation is 325. Comparing the mentioned values with the corresponding ones of Table XIII we see that they do not differ essentially from each other.

CHAPTER VI.

Apparent distribution and distribution in space of stars in the Carrington zone.

1. The number of stars here available for statistical research is 2003. Most of them, 1614 in number, are Bonn Durchmusterung stars. They are listed in Part I of the general catalogue and have been identified by means of a Bonn Durchmusterung map. The minority of the stars are not catalogued by the Bonn observers but are found in the Greenwich Astrographic catalogue, Vol. II. They are listed here in Part II of the general catalogue.

For these last mentioned stars relative positions in rectangular coordinates have been published in the Greenwich Astrographic catalogue. In order to identify them I have drawn maps following the just mentioned coordinates and have then compared my photographs with the maps. Apparent magnitudes are found in the Astrographic catalogue for certain stars of reference. For the remaining part only the diameters of the stars are available. In order to get magnitudes of such stars, I have plotted diameter against apparent magnitude for the stars of reference, and have thus obtained a relation between these quantities. Every diameter-magnitude relation was based on estimates for thirty stars on an average. About eighty such relations were drawn. The dispersions were small.

In Table XVII the stars are distributed over different spectral groups and intervals of magnitude. Two stars of the general catalogue are not included in the table. The one is a planetary nebula (known before, B. D. 83° 357), the other a star of R-type (B. D. 85° 332, also known before). It appears that the stars of groups F5 and F8 are most numerous. Their number amounts to one third of all stars. Stars of type gG0 occur extremely seldom. The same is the case with stars of types dK2—M. DYSON and MARTIN¹ have distributed the number of stars from Dec. 80° to the north pole according to effective wave-length and apparent magnitude in a table and have found a remarkably small number of stars between λ 4350 and 4400 Ångström. These stars must, according to my investigations, for the most part be stars of types gG0, and dG5—8, and these stars occur rather seldom, as is seen from the table. The observation of DYSON and MARTIN is thus confirmed in the present investigation.

8.7 per cent. of the stars are of type dG0 and only 0.4 of gG0. The corresponding numbers for the G5 stars are dwarfs 3.1 per cent. and giants 7.0. The difference between G0 and G5, which was mentioned in Chapter IV, is thus again accentuated. The number of stars with $\lambda_{\text{eff}} > 4500$ Ångström amounts to 6 per cent. in the star material used by DYSON and MARTIN. The spectral groups

¹ Loc. cit., p. 29.

Table XVII. The distribution of stars according to apparent magnitude and spectral type.

$m_p h$	Sp.	A0	A2	A3	A5	F0	F2	F5	F8	dG0	dG5	dG8	dK0	dK2	dK5	dM	gG0	gG5	gG8	gK0	gK2	gK5	gM	Totals
13.0—12.6								4	4	5				1		1	1	3	2	3			1	2
12.5—12.1		7	1			9	8	33	32	9	5	2	2	2		2	1	21	14	9	2	6	8	40
12.0—11.6								74	99	36	16	10	5	1			5	32	44	26	17	13	8	195
11.5—11.1		11	4	2	9	14	18	67	95	63	20	5	10		1		1	34	34	26	22	19	3	451
11.0—10.6		12	9	6	3	15	27	58	68	34	9	6	5	1				18	26	26	16	6	4	453
10.5—10.1		16	7	2	3	7	22	32	49	5	4	11	1	2				8	18	10	7	9	2	326
10.0—9.6		9	3	1	10	5	11	27	14	10	4	1	1					10	14	5	6	5	5	195
9.5—9.1		11	3	4	4	3	12	27	14	7	2			1				4	9	2	2	3		128
9.0—8.6		6	11		6	2	14	14	9	2	2		1					7	2	2		2	1	92
8.5—8.1		4	3	2	6	2	5	4	3	2	1		2					2	2	3			1	47
8.0—7.6		3	1	1		3	1	3	2	3	1							1	1	2	1			22
7.5—7.1		6	3		2		2	3											1	1		1		19
7.0—6.6		3	4			3	1	1	2												2		2	16
6.5—6.1		3						1																6
6.0—5.6		1	2		1	1												1						5
5.5—5.1		1																		1				3
5.0—4.6																								
4.5—4.1		1																						1
Totals		94	51	18	44	64	121	321	377	174	62	35	26	8	1	3	8	139	164	114	78	64	35	2001
Percentage		4.7	2.5	0.9	2.2	3.2	6.0	16.0	18.8	8.7	3.1	1.8	1.3	0.4	0.0	0.2	0.4	7.0	8.2	5.7	3.9	3.2	1.8	100.0

which correspond to these effective wave-lengths are gK2—M. According to my investigation 8.9 per cent. of the stars belong to these groups.

The star material here available is to be considered complete down to the apparent photographic magnitude 11.0.

2. The distances of the stars have been computed using the well-known formula

$$\log R = \frac{1}{5}(m - M) + 1$$

(after having first applied the correction mentioned on p. 28). They are listed in column "R" in the general catalogue.

A question of greatest interest is the distribution of stars in space. We shall here make it the subject of investigation, especially the decrease of star-density with distance from the galactic plane. The region of the sky here treated lies, it is true, rather near the Milky Way (gal. lat. about 27°), and accordingly the heights of the stars over the galactic plane might be expected to be relatively small, but on the other hand we have penetrated to a comparatively great depth in the line of sight; therefore the heights become after all fairly considerable. Consequently we may hope to get an idea of the thinning out of the stars from the galactic plane, at least for stars of types A0—A3 and giants of late types, which attain greater distances than stars of the other spectral groups.

We assume that, for an arbitrary volume of space, the absolute magnitudes of the stars of a given spectral group are distributed according to a normal error curve

$$\varphi(M) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(M - M_0)^2}{2\sigma^2}}$$

M_0 denotes the mean absolute magnitude and σ the dispersion. Now MALMQUIST has found that the distribution of absolute magnitudes for a given apparent magnitude m may also be considered as a normal error curve. The characteristics $\bar{M}_m$ and σ_m of this last mentioned frequency function are according to MALMQUIST¹

$$\bar{M}_m = M_0 - \frac{\sigma^2}{\log e} \cdot \frac{d(\log b(m))}{dm}$$

$$\sigma_m^2 = \sigma^2 + \frac{\sigma^4}{\log e} \cdot \frac{d^2(\log b(m))}{dm^2}$$

Here $b(m)$ is the frequency function of m . Thus $b(m)dm$ means the number of stars with an apparent magnitude $m \pm \frac{1}{2}dm$. It is obtained approximately by counting the number of stars for successive apparent magnitudes.

¹ K. G. MALMQUIST, A study of the stars of spectral type A, Lund Meddelanden, Ser. II, No. 22, 1920, p. 19.

We first make use of the above formulae for giant stars of types G0—K2. It is then necessary to know the factor $\frac{d(\log b(m))}{dm}$. We obtain it, if we draw a curve showing the relation between $\log b(m)$ and m and then compute the tangents to the curve for different values of m . Table XVIII shows the values obtained of $\frac{d(\log b(m))}{dm}$ for successive intervals of half a magnitude. The values constitute, as is easily seen, a slightly curved line.

Table XVIII.

m	$\frac{d(\log b(m))}{dm}$	m	$\frac{d(\log b(m))}{dm}$
7.8	0.7	9.8	0.4
8.3	0.6	10.3	0.3
8.8	0.5	10.8	0.3
9.3	0.4	11.3	0.3

Table XIX.

m	$\bar{M}_m$	m	$\bar{M}_m$
7.8	0.8	9.8	1.4
8.3	1.0	10.3	1.5
8.8	1.2	10.8	1.5
9.3	1.4	11.3	1.5

M_0 and σ have been deduced by MALMQUIST¹ and have the following values:

$$\begin{aligned} \text{gG} : M_0 &= -0.6 \quad (\text{visual magnitude for the distance 1 siriometer}) \\ \sigma &= 0.9 \\ \text{gK} : M_0 &= -0.2 \quad (\quad " \quad " \quad " \quad " \quad " \quad " \quad " \quad) \\ \sigma &= 0.9 \end{aligned}$$

I have accepted the value $M_0 = -0.4$. By adding 1.6 the magnitude is reduced to the usual system (distance unit 10 parsecs) and finally, adding the colour-index 0.9, we get the absolute photographic magnitude

$$M_0 = +2.1.$$

With the values of $\frac{d(\log b(m))}{dm}$, M_0 , and σ now found MALMQUIST's expression for $\bar{M}_m$ is computed. We obtain the values given in table XIX. In order to simplify the subsequent computations I have assumed $\bar{M}_m = 1.0$ for the interval $7^{m.8} - 8^{m.8}$ and $\bar{M}_m = 1.5$ for the interval $9^{m.3} - 11^{m.3}$.

For the apparent magnitudes given in Table XIX the numbers of stars are now distributed around the corresponding M_m with dispersion σ according to the demands of the error curve. See table XX.

This m , M -table is immediately converted into an m , R -table (R is the distance). See Table XXI. It shows, as is seen, the numbers of stars between different intervals of apparent magnitude and distance. The column Σ is obtained by adding the numbers of every line of the table and gives accordingly the total

¹ K. G. MALMQUIST, Researches on the distribution of the absolute magnitudes of the stars, Kungl. Svenska Vetenskapsakad. Handl., Ser. III, Band 1, No. 2, 1924, p. 73.

Table XX. Distribution of gG0—K2 stars of successive apparent photographic magnitudes over different absolute photographic magnitudes.

<i>m</i>									
<i>M</i>	<i>M_m</i>	8.0	8.5	9.0	9.5	10.0	10.5	11.0	
	2.0						1	1	1
	1.5			1	1	1	3	4	4
	1.0		1	1	3	4	6	9	11
	0.5	1	2	3	5	6	12	18	20
	0.0	1	3	4	7	9	16	24	28
	-0.5	1	3	4	7	9	16	24	28
	-1.0	1	2	3	5	6	12	18	20
	-1.5		1	1	3	4	6	9	11
	-2.0			1	1	1	3	4	4
							1	1	1

Table XXI. Distribution of gG0—K2 stars of successive apparent photographic magnitudes over different distances.

<i>R</i> parsec											Σ	<i>D_{rel}</i>	<i>R</i> parsec
724			1	3	6	16	24	28	24	16	128	0.45	650
575		1	3	5	9	16	18	16	9	5	86	0.60	516
457		2	4	7	9	12	9	7	4	2	56	0.78	410
363	1	3	4	7	6	6	4	3	1		35	0.98	325
288	1	3	3	5	4	3	1				20	1.11	259
229	1	2	1	3	1	1					9	1.00	205
182	1	1	1	1							4	0.89	164
145													
	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	<i>m</i>		

numbers of stars between the logarithmic limits of *R* listed to the left in the table. The values of *R* in the last column denote the mean distance of the intervals of the left *R*-column. Finally, *D_{rel}* is the relative space density, the density of the volume between the limits 182 and 229 parsecs being put equal to 1.00. The ratio

of the volumes is easily computed, as it is found that the volume is directly proportional to the third power of the distance.

When forming the m, R -table we have applied a correction to the star numbers for the faintest magnitudes. This is due to the fact that the actually counted numbers are too small on account of the incompleteness of the present star material below the eleventh magnitude. That it is possible to make a correction in order to get complete data also for the faintest magnitudes, is apparent from Table XXI. The successive lines of the table indicate the form of the luminosity curve for different limiting distances. We have accordingly only to complete the defective part of the luminosity curve, so that the curve becomes symmetrical. In this way part of the numbers of the first three lines of Table XXI have been corrected.

Table XXII.

Sub-class	M_0	σ	$\frac{d(\log b(m))}{dm}$
ρ, μ	0.9	0.5	0.0
κ —	1.9	0.5	0.1
κ	2.5	0.5	0.2

Table XXIII.

Sub-class	$\bar{M}_m$
ρ, μ	0.9
κ —	1.9
κ	2.4

We shall leave the group gG0—K2 for a moment and proceed to the treatment of stars of types A0—A3. For these types special sub-classes have been introduced

Table XXIV. Distribution of ρ, μ stars of successive apparent photographic magnitudes over different distances.

R parsecs												Σ
759									0.5	1	1	2.5
603									2	1		3
479							0.5	0.5	2			3
380							1.5	0.5	0.5			2.5
302						1	1.5					2.5
240					1	1	0.5					2.5
190				0.5	1							1.5
151			1	0.5								1.5
120												1.5
95		0.5	1									1.5
76	0.5	0.5										1
60	0.5											0.5
	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	m

by LINDBLAD, as mentioned before. Their mean absolute magnitudes and dispersions in magnitude have been computed, too, by LINDBLAD. Accordingly we know M_0 and σ in MALMQUIST's expression and have only to deduce $\frac{d(\log b(m))}{dm}$.

In Table XXII M_0 , σ , and $\frac{d(\log b(m))}{dm}$ are given for the three sub-classes here dealt with. M_0 and σ are taken from an investigation by LINDBLAD and SCHALÉN.¹

Table XXV. Distribution of κ -stars of successive apparent photographic magnitudes over different distances.

R parsecs																Σ
603															0.5	0.5
479													0.5	1	0.5	2
380										0.5	1	1				2.5
302										2	1					3
240									1	2	0.5					3.5
190								0.5	1	0.5						2
151							0.5	1	0.5							2
120						1.5	1									2.5
95						0.5	1.5									2
76					0.5	0.5	0.5									1.5
60				0.5												0.5
48																
38																
30	0.5															0.5
24	0.5															0.5
	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	m		

The factor $\frac{d(\log b(m))}{dm}$ has been found to be constant within each sub-class for the magnitudes here considered.

For $\bar{M}_m$ we now deduce the values of Table XXIII. The numbers of stars are then distributed for each sub-class separately in an $m, \bar{M}$ -table and an m, R -

¹ Loc. cit., p. 13.

table in the same way as for the giants of late types. The distributions according to m and R are given in Tables XXIV–XXVI. In table XXVII the numbers of stars of the different sub-classes are collected. It illustrates accordingly the distribution for all stars of types A0–A3.

The relative star-density, D_{rel} , is now known for group gG0–K2 as well as for A0–A3 stars. We shall discuss it briefly.

Table XXVI. Distribution of $\times$ stars of successive apparent photographic magnitudes over different distances.

R parsecs															Σ
759										0.5	3.5	9	15	9	41
603										3	9	12	9	3	36
479									1	7.5	9	7.5	1		26
380								1.5	3	7.5	3.5	1.5			17
302							1.5	3.5	3	3	0.5				11.5
240						0.5	3.5	3.5	1	0.5					9
190					1	3.5	1.5								6
151				0.5	1	1	1.5								4
120				1	1	0.5									2.5
95			0.5	1											1.5
76			0.5	0.5											1
60	0.5														0.5
48	0.5														0.5
38															
	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	m

D_{rel} for the A stars is put equal to unity for $R=170$ parsecs, as is seen from Table XXVII. For shorter distances D_{rel} then assumes greater values than unity. However, these great densities must probably be considered quite unreliable, as they are based on relatively small numbers of stars.

Instead of R we now introduce H , the height above the galactic plane. $H = R \sin B = 0.454 R$. The galactic latitude is here put equal to 27° . In the right part of Table XXVIII D_{rel} is listed for the A stars as well as for the stars of types gG0–K2, together with the corresponding R and H . It appears from the table that the density for the A stars decreases very rapidly as we leave the galactic plane. If the density is 1.0 at the height 77 parsecs, we see that it has

Table XXVII. Distribution of A0—A3 stars (the numbers of all sub-classes collected) of successive apparent photographic magnitudes over different distances.

<i>R</i> parsecs																	Σ	D_{rel}	<i>R</i>
759									0.5	1	1.5	3.5	9	15	9		43.5	0.07	681
603									2	1	3.5	9	12	9	3		39.5	0.13	541
479								0.5	0.5	2.5	2	8	9	7.5	1		31	0.20	430
380								1.5	1	3	4	7.5	3.5	1.5			22	0.29	341
302																			
240						1	1.5	3.5	4.5	3	3	0.5					17	0.45	271
190					1	1	2	5.5	4	1	0.5						15	0.79	215
151				0.5	1	0.5	2	4	1.5								9.5	1.00	170
120			1	1	1.5	1.5	1	1.5									7.5	1.6	135
95		0.5	1	1.5	2	1	0.5										6.5	2.7	107
76	0.5	0.5	0.5	2	1												4.5	4	86
60	0.5	0.5	0.5	1	0.5												3	5	68
48		1															1	3	54
	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	<i>m</i>			

decreased to 0.5 already at about 120 parsecs. And at 300 parsecs it is quite inconsiderable. If we compare these conclusions with the corresponding ones drawn by LINDBLAD¹, who has examined the star-density for the region with its centre at $L=103^\circ$, $B=+46^\circ$, we find that they are in close agreement. In the left part of Table XXVIII D_{rel} found by LINDBLAD is listed together with the corresponding R and H . At the height 72 parsecs unit density is assumed. At about 130 parsecs it has decreased to half, and at 300 parsecs it is insignificant. According to VAN RHIJN² the density should not decrease so rapidly. He has investigated the density function for different galactic zones. The one which allows a direct comparison with my region is the zone $\pm 20^\circ \pm 40^\circ$. Assuming unit density for this zone at the same height as for the present region we find that the density has not decreased to the half until at about the height 175 parsecs above the galactic plane.

For the group gG0—K2 I have assumed unit density for $R=205$ or $H=93$ parsecs. (See Table XXVIII.) It appears from the table that we may consider the

¹ B. LINDBLAD, On the decrease of star-density with distance from the galactic plane, Arkiv f. mat., astr. o. fys., Band 19 B, No. 15, 1926.

² P. J. VAN RHIJN, On the frequency of the absolute magnitudes of stars, Gron. Publ., No. 38, 1925.

Table XXVIII. Star-densities at different heights over the galactic plane for the examined region.

Lindblad						Petersson							
R parsecs	H parsecs	B8—A3		gG0—K2		R parsecs	H parsecs	A0—A3		R parsecs	H parsecs	gG0—K2	
		D_{rel}	D_{abs}	D_{rel}	D_{abs}			D_{rel}	D_{abs}			D_{rel}	D_{abs}
80	58	0.7	0.25	1.00	0.48	135	61	1.6	0.42	164	74	0.89	0.12
100	72	0.96	0.35	0.80	0.39	170	77	1.00	0.26	205	93	1.00	0.14
127	91	0.76	0.27	0.75	0.36	215	98	0.79	0.21	259	118	1.11	0.16
160	115	0.63	0.23	0.55	0.27	271	123	0.45	0.12	325	148	0.98	0.14
200	144	0.35	0.13	0.40	0.19	341	155	0.29	0.07	410	186	0.78	0.11
253	180	0.17	0.06	0.33	0.16	430	195	0.20	0.05	516	234	0.60	0.08
319	230	0.08	0.03	0.24	0.12	541	246	0.13	0.03	650	295	0.45	0.06
400	290	0.04	0.01	0.20	0.10	681	309	0.07	0.02				

density as approximately constant to a height of about 150 parsecs. If we go farther away from the galactic plane, the density decreases, but much slower than for the A stars, and reaches half of its original value at about 270 parsecs in height. According to LINDBLAD (see the left part of the table) the density should decrease continuously from the height 58 parsecs. Assuming unit density for $H=150$ parsecs as for my region we find that the density attains the value 0.5 at about 300 parsecs in height. The agreement with my result is accordingly rather good, and it is obvious that the rate of density-decrease for heights greater than 150 parsecs is about the same in both cases.

The absolute densities, D_{abs} , which are listed together with D_{rel} in Table XXVIII, have been obtained from D_{rel} after having first computed the real density which corresponds to D_{rel} at a certain distance. Putting the focal length of the instrument used equal to 150 cm and the area of plates equal to $4 \times 12 \times 15 = 720 \text{ cm}^2$ (four regions) I find for the group gG0—K2 that the number of stars is 0.141 per thousand cubic parsecs at the distance 205 parsecs. For the A stars the number becomes 0.260 per thousand cubic parsecs at the distance 170 parsecs. In LINDBLAD's case the absolute density corresponding to $D_{\text{rel}}=1$ for gG0—K2 is equal to 0.485 stars per thousand cubic parsecs and for B8—A3, 0.360.

In Figure 18 the relations between D_{abs} and the height over the galactic plane are given according to Table XXVIII. The conclusions which have been drawn above with the aid of D_{rel} are accentuated by the figure. Moreover, we now find that the real star-density is considerably greater for gG0—K2 than for A0—A3, at least at great heights above the galactic plane. For LINDBLAD's region we arrive at the same result. (See Figure 19.) LINDBLAD's absolute densities for gG0—K2 are, however, throughout greater than mine. (See Figure 20.) For the A stars (Figure 21) LINDBLAD's values of D_{abs} are greater than mine for heights < 185 parsecs, for greater heights, on the other hand, they are nearly the same.

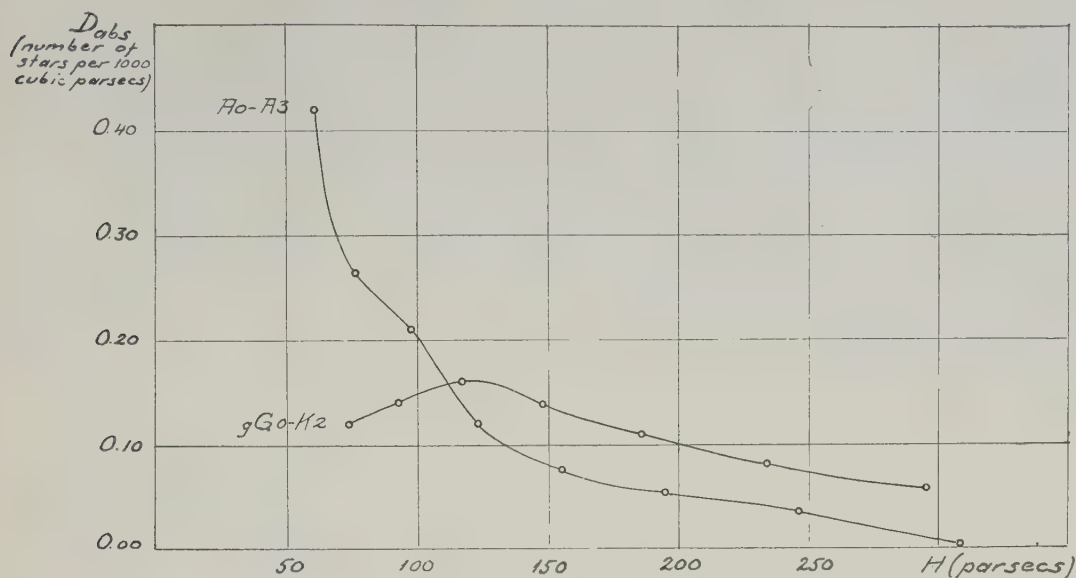


Fig. 18. Relation between absolute density and height over the galactic plane for PETERSSON's region.

Let us now compute for both LINDBLAD's and my region and for white and red stars separately the heights over the galactic plane which correspond to succes-

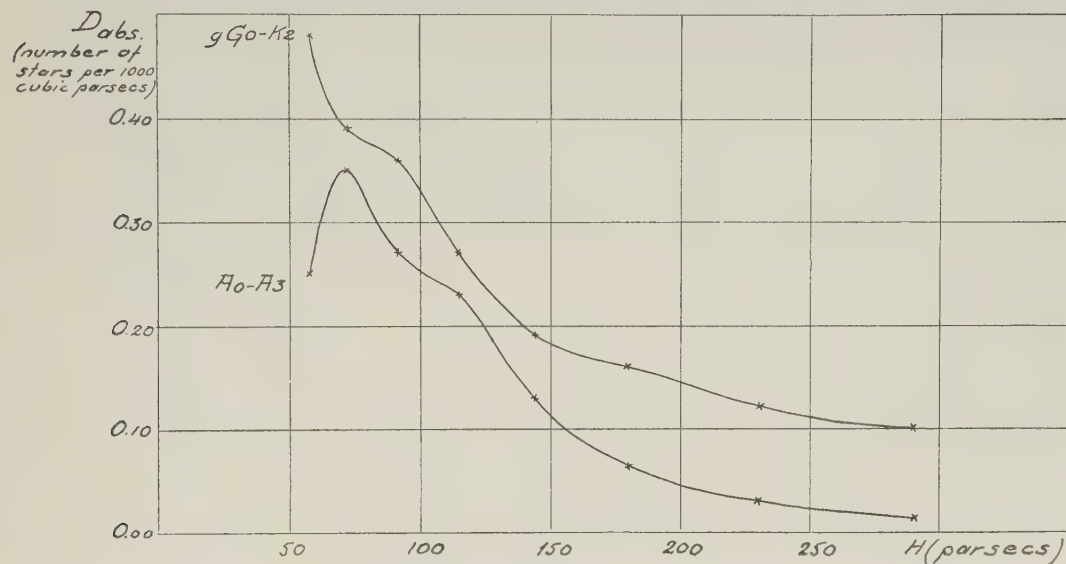


Fig. 19. Relation between absolute density and height over the galactic plane for LINDBLAD's region.

sive values of the absolute density. The result is easily obtained from Figures 20 and 21 and have been listed in Table XXIX. H_L and H_P are the heights in

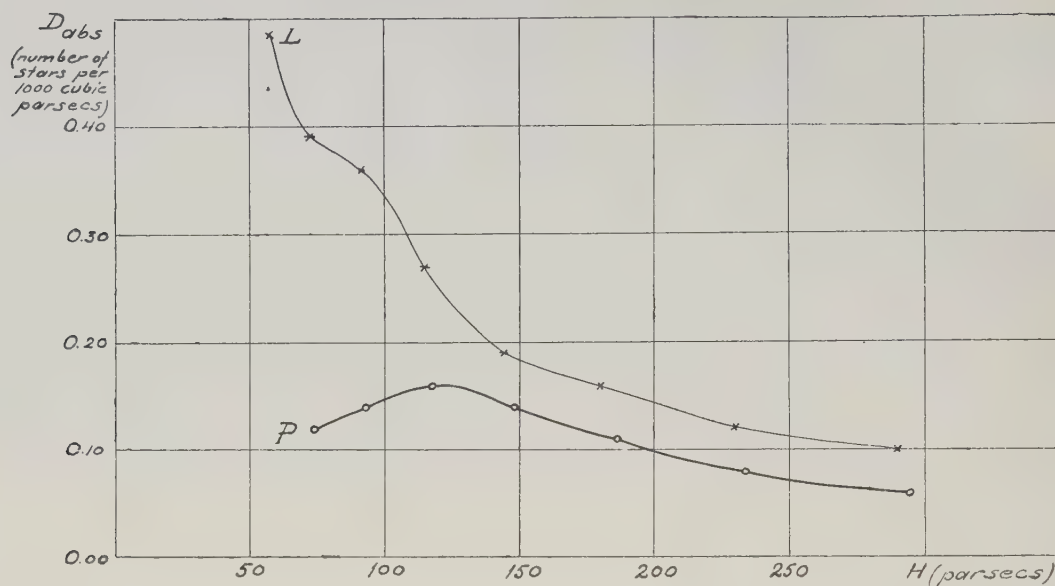


Fig. 20. Density-curves according to LINDBLAD (L) and PETERSSON (P) for gG0—K2 stars.

LINDBLAD's and my region respectively. Figures 22 and 23 illustrate the result. The lines which are denoted "LINDBLAD" and "PETERSSON" are drawn with inclina-

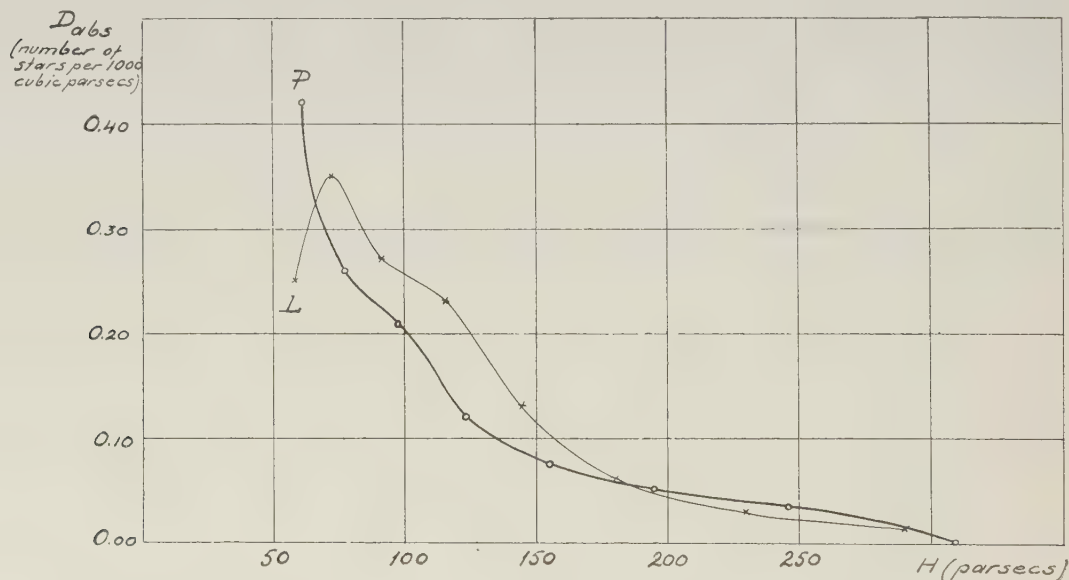


Fig. 21. Density-curves according to LINDBLAD (L) and PETERSSON (P) for A0—A3 stars.

tions with respect to the galactic plane equal to the galactic latitudes of the two regions. The traverse lines accordingly show the real inclination with respect to

the galactic plane for layers of equal density. If we first consider Figure 22 we see that the inclination of the density-lines for the A stars is rather variable. *For great heights*, however, and accordingly for densities which are computed from relatively large star numbers *the density-lines are nearly parallel to the galactic plane*. The figure illustrates also very plainly the rapid thinning out of A stars, as we leave the galactic plane.

For the group gG0—K2 (Figure 23) the density-lines are more separated from one another than is the case for the A stars, which is quite natural, as the density decreases more slowly for the former group. The inclination of the lines with respect to the galactic plane is rather great. Whether the layers in reality show such an inclination or not may be difficult to decide. Assuming it to be real we must infer that the star-density is greater in the direction examined by LINDBLAD than in the direction of my region. But, on the other hand, we may assume that the layers of equal density really lie parallel to the galactic plane. Their inclination according to the figure may then be due to a systematic difference

between my determinations of distances and LINDBLAD's. Such a difference would arise, if the absolute magnitudes adopted by me for the computation of distances were systematically brighter than those used by LINDBLAD.

An increase of my absolute magnitudes may in reality be justified, at least for the brightest stars. In fact, I have not adopted quite the same $\bar{M}_m$ (see MALMQUIST's expression) as LINDBLAD, due to the circumstance that LINDBLAD assumed the factor $\frac{d(\log b(m))}{dm}$ to be constant and equal to 0.4 for all apparent magnitudes m , while I have assumed it to vary somewhat with m . See Table XVIII. Accordingly $\bar{M}_m$ is not constant for all apparent magnitudes and equal to +1.4 as in LINDBLAD's case. I have adopted the value $\bar{M}_m = +1.0$ for stars brighter than $9^{m.0}$ and $\bar{M}_m = +1.5$ for stars fainter than this magnitude. If the adopted $\bar{M}_m$ for the brightest stars is too small, the inferred distances become too great and the absolute density therefore too small. It is for this reason natural that the density-lines are inclined with respect to the galactic plane in the way shown by Figure 23.

In order to find the inclinations, if we assume $\bar{M}_m = +1.4$ in my case, too, I have distributed the stars in m , M - and m , R -tables and computed new densities. We find (Figure 24) that my density-curve now agrees better with LINDBLAD's than before (Figure 20). With the help of Figure 24 we obtain Figure 25. It shows

Table XXIX. Heights over the galactic plane corresponding to different values of absolute density.

D_{abs}	B8—A3		D_{abs}	gG0—K2	
	H_L	H_P		H_L	H_P
0.35	72	64	0.16	180	124
0.30	84	69	0.15	192	138
0.25	104	80	0.14	206	148
0.20	125	101	0.13	218	158
0.15	139	115	0.12	230	170
0.10	156	132	0.11	254	186
0.08	167	150	0.10	290	200
0.055	185	185			
0.04	204	226			
0.02	254	280			

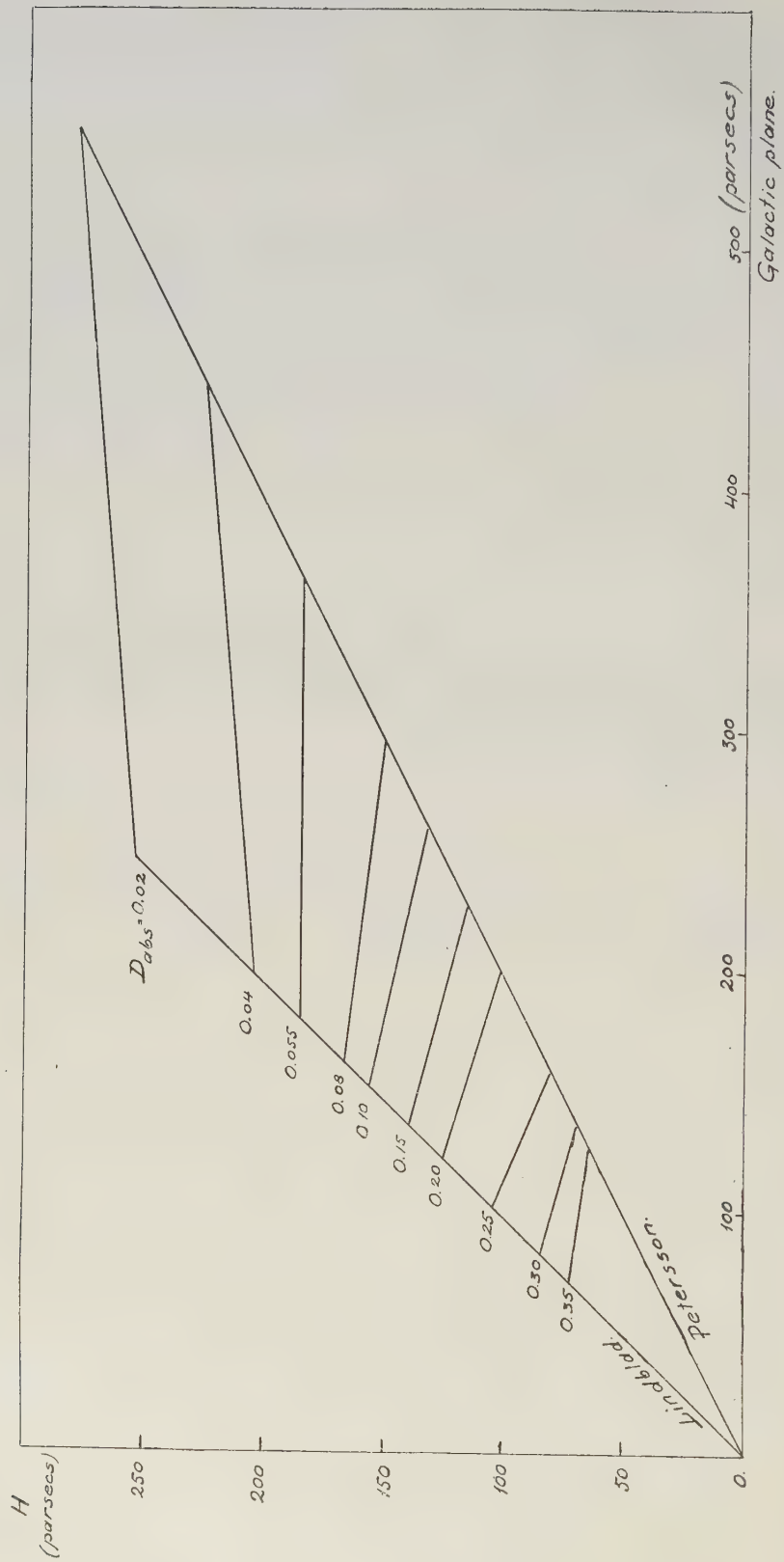


Fig. 22. Diagram showing the positions of layers of equal star-densities with respect to the galactic plane.
Stars of types A0—A3.

that the inclinations of layers of equal density are smaller than in the case of a variable $\bar{M}_m$ for my region.

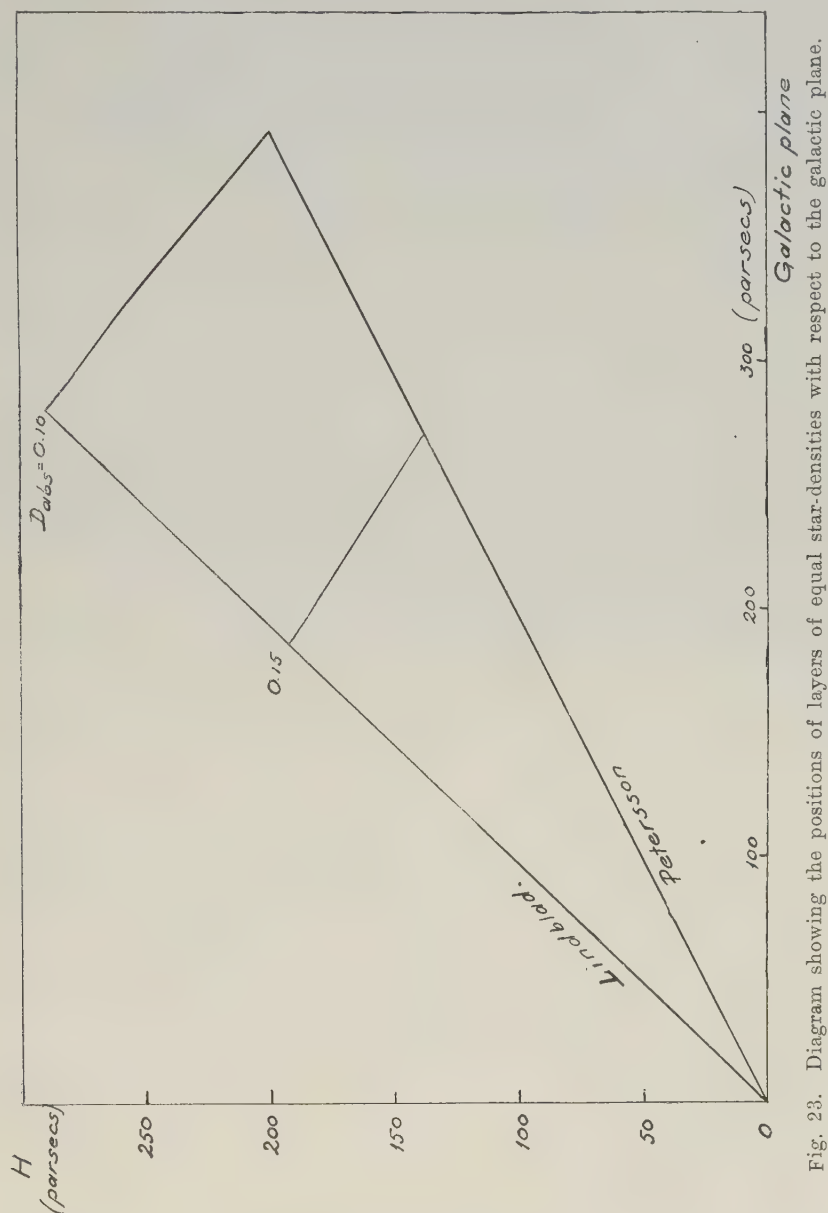


Fig. 23. Diagram showing the positions of layers of equal star-densities with respect to the galactic plane. Stars of types G0—K2.

In order to get a clear idea of the positions of layers of equal density relative to the galactic plane one must know the densities in several directions. A direction for which data exist is the one towards LINDBLAD's first region with centre at $L = 84^\circ.5$, $B = +14^\circ$. The galactic latitude of the region is, however,

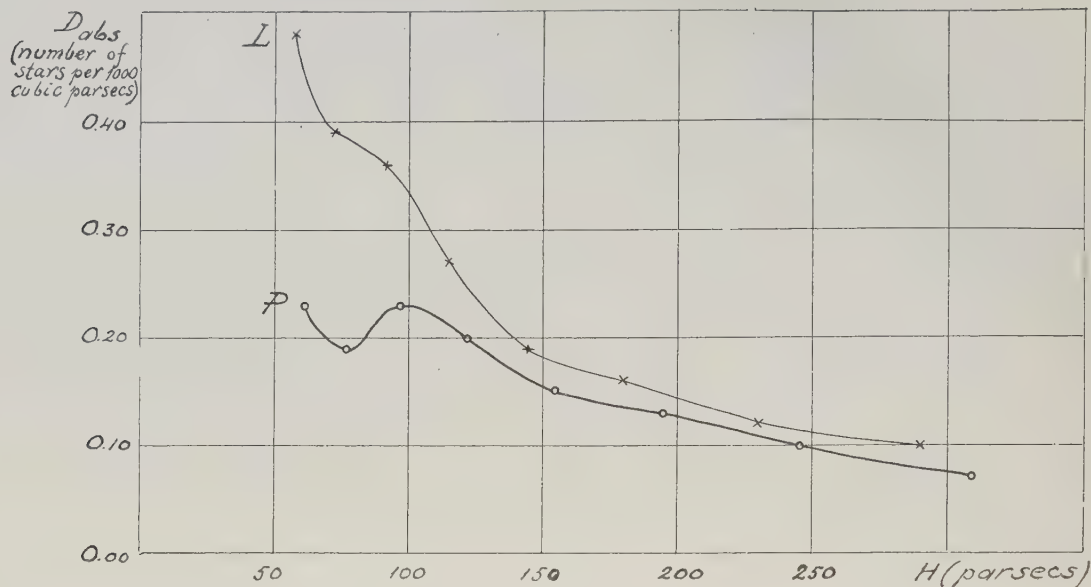


Fig. 24. Density-curves of gG0-K2 stars derived assuming a constant M_m .

too low as to allow us to attain considerable heights over the galactic plane even for great distances in the line of sight. The region is accordingly not satisfactory for giving an idea of the decrease of star-density with distance from the galactic plane. It would be especially valuable to know the distribution of densities in a direction somewhat nearer the galactic pole than the ones investigated by LINDBLAD and me.

For other spectral groups than A0-A3 and gG0-K2 it is not possible with the present data to obtain densities for great heights above the galactic plane.

Table XXX. Numbers of A stars of different sub-classes and absolute magnitudes.

$R < 240$ (parsecs)					$R > 240$ (parsecs)				
Group M	ρ, μ	$\kappa -$	κ	Totals	Group M	ρ, μ	$\kappa -$	κ	Totals
0.15					0.15	0.5			0.5
0.65	3.5			3.5	0.65	5			5
1.15	4.5	0.5		5	1.15	5	1		6
1.65	0.5	5.5	1	7	1.65	0.5	4.5	10.5	15.5
2.15		7.5	7.5	15	2.15		2.5	32	34.5
2.65		1.5	11	12.5	2.65			46.5	46.5
3.15			5	5	3.15			32	32
3.65			0.5	0.5	3.65			9.5	9.5

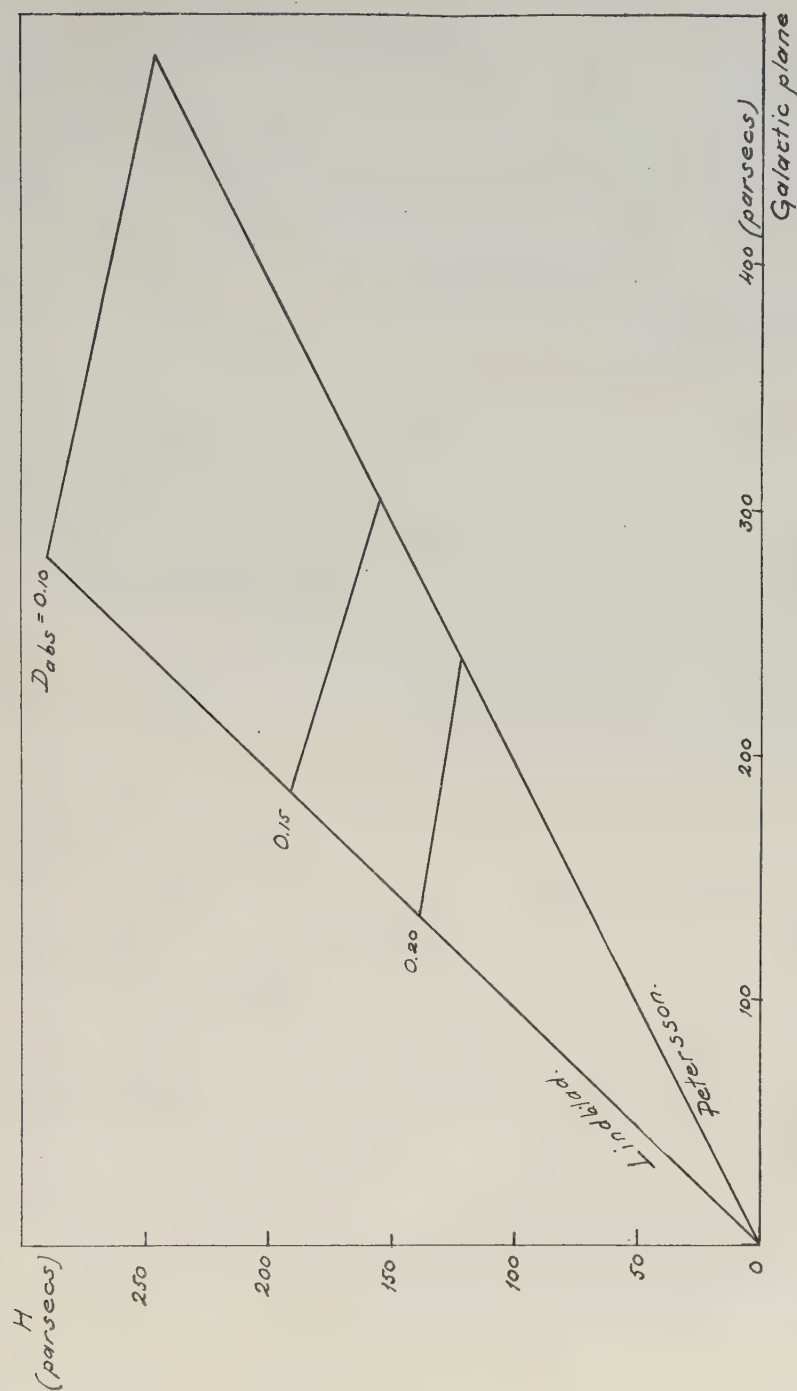


Fig. 25. Diagram showing the positions of layers of equal star-densities with respect to the galactic plane.
Stars of types $gG0-K2$. (Constant M_m)

3. Finally we shall examine the form of the luminosity curve of the A stars. As the curve is possibly not the same for the remoter stars as for the nearer ones, we divide them into two groups, namely, into stars with $R < 240$ parsecs and into stars with $R > 240$ parsecs. Table XXX gives the numbers of stars for different absolute magnitudes and sub-classes for the two groups. The numbers have been obtained from Tables XXIV, XXV and XXVI by adding the numbers of stars along the oblique lines. The numbers in Table XXX are now reduced to be valid for equal volumes, whereafter the two luminosity curves have been drawn. They are not, however, directly comparable, because they involve the star-density. We eliminate the

density by assuming $\int_{-\infty}^{+\infty} \varphi(M) dM = 1$ for the areas between the curves and the coordinate axis M . In this way the luminosity curves of Figure 26 are finally obtained.

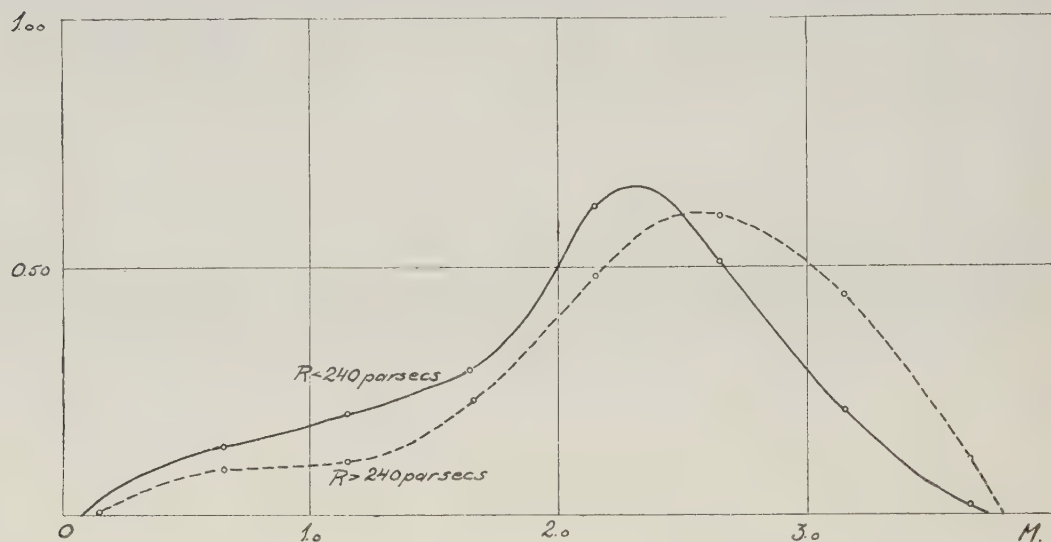


Fig. 26. Luminosity curves of A0—A3 stars.

It is obvious that the frequency of M cannot be represented by a normal error curve. The maximum of frequency is attained at $M = +2.3$ for stars with $R < 240$ parsecs and at $M = +2.6$ for stars remoter than this distance. The brightest magnitudes seem to have a tendency to form a maximum, too, as is well seen from the figure. To these magnitudes the A stars with narrow hydrogen lines correspond. The fact that the maximum of frequency is displaced towards fainter absolute magnitudes with increasing distance of the stars, as indicated by the figure, is worth notice. The displacement is small, it is true, amounting to only 0.3 magnitude in the present case, but it seems to show that the distribution of absolute magnitudes is probably not quite independent of the distance, as is often assumed in statistical investigations.

4. The present paper treats only a part of the Carrington zone. It is intended to investigate the remaining part in the near future. With data from the whole zone we may hope that the conclusions given in the present paper will get a still stronger support.

CHAPTER VIII.

Introduction to the General catalogue.

The catalogue consists of two parts. Part I includes 1614 Bonn Durchmusterung stars from 82° to 88° declination. The stars of Part II are from the same declinations but have, on account of their faintness, not been listed by the Bonn observers. They are found in the Greenwich Astrographic catalogue, Vol. II, and are 389 in number. The star material is to be considered complete down to the apparent photographic magnitude 11.0.

The first column of Part I gives the stars according to Bonn Durchmusterung number. The apparent magnitudes of the next column have been determined at Greenwich and have been corrected to the International System by applying the corrections of Harvard Annals 71, p. 224, and of Harvard Bulletin 781. The columns headed "Sp. U." and "Sp. H." contain spectral types estimated at Upsala by me and at Harvard (Draper catalogue) respectively. The prefixes "g" or "d" for late type stars indicate giant or dwarf character. For the A stars special sub-classes have been adopted. Concerning their meaning I refer to the scheme of classification p. 8 of the present paper. Column five gives effective wave-lengths (in Ångström units) determined at Greenwich. The values with the sign : are based on measurements on one plate only. $\log E_G$ of the next column is the colour-effect for two spectral regions adjacent to the band G ($G-\lambda 4383$ and $\lambda 4227-G$). $\log E_N$ denotes the equivalent of cyanogen absorption in the band $\lambda 4216$. It is formed by comparing the regions $\lambda\lambda 4144-4184$ and $\lambda\lambda 4227-4272$. The values of $\log E_G$ and $\log E_N$ are based on measurements from at least two spectral images. For a star of the apparent magnitude 10.5 measurements from about two spectral images have been performed, for the magnitude 9.0 from five images, and for $7^m.0$ from about 9 images. $\log E_G$ and $\log E_N$ are logarithmic exposure ratios expressed in the unit 0.15. We obtain the corresponding differences in magnitudes by multiplication with the factor 0.3. Column M_{ph} gives absolute *photographic* magnitudes. These have been obtained by applying relations determined by LINDBLAD. (See pp. 8 and 10 of the present paper.) Finally R gives the distances of the stars in parsecs obtained by means of the estimated absolute magnitudes. In cases where no estimations have been made mean absolute magnitudes for different spectral groups have been adopted.

Part II of the General catalogue gives the stars according to the numbers of the Greenwich Astrographic catalogue, Vol. II. The stars with $\text{Dec.} \geq 87^\circ$ are in the Astrographic catalogue numbered for each plate separately. The denotations at the end of Part II accordingly refer to the number of the plate and the number of a given star on the plate. The parenthesis includes a reference to a certain page of the Greenwich Astrographic catalogue, Vol. II.

As a rule apparent magnitudes are not given in the Greenwich catalogue for these faint stars but only diameters. The magnitudes listed in Part II have been obtained from relations between diameter and apparent magnitude for certain stars of reference.

CHAPTER IX.

GENERAL CATALOGUE.

Part I.

B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs	B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs
81° 20	8.9	A2 κ		4277			2.5	190	82° 22	9.5	A0 κ		4272			2.5	251
21	11.2	gK2						794	23	8.2	d:G0:	F8	4288				
23	9.2	dG5		4383	0.42	0.00	6.3	35	24	9.7	F0		4249				229
24	11.3	gK0:						759	25	10.2	F8		4305				132
28	9.9	gK0		4464				398	26	10.5	dG5		4346:				100
171	9.8	dG0		4332				87	27	11.2	gK5:						724
172	11.1	dG0		4308				158	28	10.6	gM						549
173	10.7	A0 κ		4267			2.5	436	29	10.5	d:G8		4404				
789	8.8	gG8	K0	4421	0.80	0.93	0.8	363	30	8.7	A2 κ	A2	4258			2.5	174
791	11.6	gK5:						871	31	10.4	F5		4282				199
793	12.0	gK5:						1047	125	7.4	A0 κ —	B9	4252			1.3	166
803	10.4	gK0		4488				501	126	11.0	gK2		4505				724
809	10.8	g?G5							127	9.8	F5		4277				151
821	10.2	A2 κ		4258			2.5	347	128	10.1	F2		4281				229
828	11.4	gK5						794	129	10.6	dG0		4334				126
832	8.9	dG0	K0	4352	0.37	0.00	6.0	35	130	10.5	gK0		4486				525
82° 1	10.0	F5		4304				166	131	11.0	gG5		4336:				692
2	9.9	gG8		4466	1.06	1.09	1.5	436	132	9.0	gG8	K0	4419	0.77	0.81	1.4	302
3	10.2	gK2		4513				501	133	9.0	F2	F2	4264				138
4	8.9	F5		4251				100	134	10.9	F8		4285				182
5	9.7	gM		4570				363	135	10.0	A2 κ		4257			2.5	316
6	10.8	F8						174	136	9.2	A0 μ		4234			1.0	436
7	10.6	F5		4344:				219	137	11.2	dG8:						126
8	9.9	F2		4271				209	138	10.0	F8		4274				120
9	10.7	dG0		4299:				132	139	10.8	gG8		4457				575
10	10.9	gK5		4522:				631	140	11.2	gK2						794
11	10.4	gK0		4463				501	141	9.8	A3 κ		4258			2.5	288
12	10.5	F8		4324				151	142	11.0	F5		4274:				263
13	10.8	F5		4257				240	143	9.7	gG8		4434	0.77	0.73	1.9	331
14	8.0	A3 κ	A2	4272			2.5	126	144	10.0	F5		4278				166
15	10.2	gG8		4455				436	145	11.0	gG5		4390:				692
16	11.4	dK5						55	146	10.4	F5[A2]		4262				199
17	9.5	F5		4264				132	147	10.4	gG8		4446	0.77	0.77	1.6	525
18	11.3	gK2						832	148	10.3	F2		4265				251
19	9.9	F8		4290				115	149	11.6	gG8						832
20	6.0	A2 κ —	A2	4282			1.9	66	150	11.2	gG8						692
21	9.2	A0 μ		4254			1.0	436	151	9.8	A5		4279				263

B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs	B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs
82° 152	7.9	F8	F8	4273:				46	82° 319	11.9	dK2:						100
153	10.1	gK2		4516	1.54	1.26	1.5	479	321	9.6	F5		4277				138
154	10.3	F2		4263				251	322	9.4	F8	F8	4286				91
155	9.7	gK2	K0	4515	1.60	1.13	1.5	398	323	10.6	F5		4266:				219
156	10.5	A3 κ		4261:			2.5	398	324	10.2	F5		4247				182
157	11.1	gG8		4450:				661	325	7.7	dG0	G0	4334	0.23	0.16	4.0	50
158	10.7	F2		4238:				302	326	10.1	gK5		4554				436
160	11.1	dG5		4333:				132	329	11.7	gK5:						912
161	10.2	dG0		4307	0.26	0.28	2.9	251	332	9.2	F8	G0	4290				83
162	10.6	gK0		4426:				549	333	10.8	d:G8						
163	10.8	F5		4354:				240	335	10.9	gG8		4465:				603
164	11.3	gG8						724	340	10.3	gG8		4452	0.80	0.95	0.8	724
165	11.2	dG0		4273:				166	342	9.2	gG8	G5	4433	0.88	0.86	1.7	288
166	11.1	dG5		4368				132	345	10.4	F8		4318				144
167	11.0	d:G0		4360:					347	10.9	gK0		4473				631
168	9.1	F8	G0	4293				79	348	9.4	F5	F8	4262				126
169	10.1	gK2		4514	1.71	1.52	1.5	479	351	9.7	F5		4287				144
171	11.4	gG5						832	353	11.6	gK2						955
172	10.6	A2 κ		4248			2.5	417	365	8.3	F5	F5	4295				76
174	9.5	dG0	G	4335	0.17	0.13	4.1	110	368	9.9	dG0		4356	0.13	0.00	5.3	76
175	10.6	F8		4330				158	371	11.4	gG8						759
176	9.5	gG8	K0	4485	0.91	0.95	1.4	300	378	9.1	F5:	A3	4280				110
177	6.8	A2 κ	A2	4267			1.9	95	380	11.2	gG5?						
178	10.5	F5		4285				209	381	11.2	F8:						209
179	10.4	F0		4278				316	495	11.3	gG5?						
180	10.7	gK2		4542:				631	496	9.7	gG5		4399	0.73	0.69	1.9	331
181	10.9	gK0		4495:				631	497	8.9	F0	F0	4262				158
182	11.2	gK5						724	498	5.4	gG5	G0	4408	0.67	0.59	2.4	36
183	10.4	F8		4336				144	500	10.9	gG5		4368:				661
184	10.0	dG8		4383	0.58	0.19	5.1	87	501	10.5	F5		4237:				209
185	9.8	gK5	K2	4548				380	502	10.7	F5		4312				229
186	10.9	F5		4274				251	503	11.2	A0: κ		4263			2.5	549
187	10.1	F2		4264				229	504	10.9	gK2		4559				692
188	9.5	gK5	K2	4538				331	506	10.2	F5		4294				182
189	9.4	A3 κ	A2	4279			2.5	240	507	9.8	F5		4280				151
190	9.9	F5		4289				158	508	10.0	dG8		4414	0.74	0.17	5.8	63
191	9.8	gK2	K2	4506				417	509	10.9	F5		4292				251
192	11.0	dG5		4320:				126	510	11.2	F8						209
193	11.2	dG5						138	511	11.4	gG8						759
194	8.9	gK5	K5	4561				251	513	11.3	F8:						219
196	10.8	F5		4277				240	515	11.8	gK0:		4499:				955
201	6.7	gM	Ma	4538				91	516	11.4	F8		4324				229
314	10.7	F8		4316:				166	517	11.0	gG8		4495				631
315	10.5	A0 κ		4232			2.5	398	518	9.1	gG5	K0	4433	0.55	0.75	0.5	479
317	10.7	F5		4278				229	519	10.7	F8		4292				166
318	10.9	F8		4278				182	520	11.0	F2		4306				347

B. D.	m_{ph}	Sp. U.	Sp.H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs	B. D.	m_{ph}	Sp. U.	Sp.H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs
82° 521	8.3	A0 μ	A0	4238			1.0	288	82° 572	6.7	A0 ρ	A0	4228			0.9	144
522	10.3	dG8		4385	0.60	0.24	4.8	115	573	11.1	gK0						692
523	9.5	F5	F5	4271				132	574	11.7	gK0						912
525	10.1	gG5		4445	0.71	1.05	-0.4	1148	576	11.8	gK0:						955
526	11.3	dG0		4355:				174	690	11.6	gK2:						955
527	11.6	gG8						832	696	10.8	gG8		4423:				575
528	10.8	F8		4300				174	697	11.6	gK5:						871
529	10.5	dG8		4434	0.71	0.08	6.5	58	698	9.6	F5		4248				138
530	11.6	gG5						912	699	10.0	F8		4282				120
533	11.6	dG5						166	700	7.3	A0 ρ	B8	4241			0.9	190
534	9.8	gG5		4425	0.77	0.73	1.8	363	701	12.2	gK5:						1148
535	9.7	F5		4277				144	702	10.3	F2		4282				251
536	10.7	F8		4279:				166	703	6.1	gK2	K0	4517	1.48	1.05	2.8	42
537	9.6	gK0	K2	4487	1.08	1.35	0.8	525	704	8.3	dK0	K2	4404	0.77	0.00	7.4	14
538	11.0	F5						263	705	11.0	F8		4271:				190
539	8.9	A2 κ -	A0	4258			1.9	251	706	9.8	F8		4268				110
540	7.2	A0 σ	B9	4189			0.2	251	707	9.4	gK0	K0	4431	1.06	1.06	1.7	316
541	10.5	gG8		4463				501	708	10.6	F8		4273				158
542	10.0	gK5		4548				417	709	10.9	F0		4316				398
543	9.2	gG8	K0	4436	0.81	0.65	2.7	182	710	10.2	F8		4276				132
544	8.6	F2		4265				115	711	10.4	gK2		4548				549
545	10.9	F5		4314:				251	712	9.6	A0 κ		4236			2.5	263
546	9.1	gK0	K0	4484	1.08	0.94	2.3	209	713	10.6	gG8		4434				525
548	11.3	F2:		4246:				398	714	10.2	F8		4266				132
549	10.6	F2		4274				288	716	10.1	gK0		4476				436
551	10.8	A2 κ		4263			2.5	457	717	11.8	gK2						1047
552	11.7	F5						363	718	11.6	F5						347
553	10.7	F8		4300				166	719	11.0	A2 κ		4268:			2.5	501
554	9.7	gG8		4459				347	720	9.4	F2	F5	4287				166
555	11.8	gG5:						1000	721	11.3	gK5						759
556	11.1	gG5						724	722	10.0	A0 κ		4267			2.5	316
557	10.9	F0		4250:				398	723	10.5	gK5		4545				525
558	11.3	dG0						174	724	11.8	F8						275
559	10.3	F5		4263				190	725	11.1	dG0						158
560	11.8	gG5						1000	726	10.2	F0[A2]		4268				288
561	10.2	F8		4279				132	727	9.7	dG5		4338	0.61	0.00	6.9	33
562	9.0	F5		4282				105	728	8.5	gK0	K0	4462	1.08	0.83	2.7	132
563	11.1	F8						199	729	10.4	A5		4292				347
564	10.4	F8		4272				144	730	10.1	F5		4254				174
565	9.7	F8		4298				105	731	10.5	dG0		4300				120
566	11.4	gG8						759	732	10.2	A0 κ		4260			2.5	347
567	10.6	F2						288	733	9.2	dK2		4455	1.13	0.28	6.7	29
568	12.0	gM:						1047	734	11.9	gK5						1000
569	11.2	F5		4301:				288	735	8.7	gG8	G5	4412	0.90	0.70	2.6	151
570	10.8	gK0		4458				603	736	8.6	F2	F0	4270				115
571	10.4	A0 μ		4232			1.0	759	737	11.5	F5?						

B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs	B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs
82° 738	11.5	gK2:						912	83° 116	10.5	dG0		4351	0.28	0.00	5.8	79
739	11.4	gG8						759	117	10.6	F2		4253				288
740	9.5	F5		4264				132	118	8.9	gG5		4396	0.65	0.63	2.0	219
741	11.0	A5:						457	119	10.6	F8		4304:				158
742	9.9	F8		4300				115	120	10.2	gG8		4456	0.84	0.75	2.1	380
743	6.7	A0 $\approx$	A0	4246			2.5	69	121	8.3	F5	F5	4287				76
744	10.2	F5		4275				182	122	10.3	F8		4286				138
745	11.2	gK2						794	123	9.6	gG8		4446	0.91	0.52	3.8	132
746	11.1	gM						692	124	10.4	F5		4284				199
747	10.5	F5		4283				209	125	10.3	gG8		4487	0.91	0.91	1.6	501
748	7.1	A0 μ	A0	4255			1.0	166	126	9.0	gK2	K2	4520	1.75	1.62	1.5	288
749	11.4	gK5						794	127	10.1	F5		4302				174
750	9.7	F5		4263				144	128	10.8	F8		4305				174
751	10.9	F8		4268:				182	129	9.5	gG8		4461	0.80	0.91	1.0	457
83° 1	8.4	F2	F	4277				105	130	9.8	gM		4565				380
2	10.4	gG8						479	131	10.9	F8		4356				182
3	9.2	F5		4292				115	132	10.7	gK2		4495				631
4	10.3	F5		4286				190	133	10.8	F8		4312:				174
5	10.3	dG5		4375				91	134	11.0	F8		4291				190
6	10.0	gG8		4436				398	135	11.2	dG0						166
7	9.9	F0		4286				251	136	11.2	gG8		4450				692
8	10.3	gK5		4522				479	137	8.6	F2	F5	4288				115
9	7.4	F5		4320				50	138	9.6	F8		4332				100
10	8.3	F8		4323				55	139	9.5	dG0	G0	4351	0.28	0.19	3.9	120
11	8.6	F2		4301				115	140	10.6	dG5		4369				105
12	9.6	F5		4293				138	141	7.0	A0 σ —	A0	4258			0.2	229
13	10.6	F8		4296				158	142	9.9	gM	K5	4556				398
14	10.6	A0 $\approx$		4299			2.5	417	143	12.1	dM						60
15	8.9	F5		4312				100	144	9.9	gK0	K0	4491	0.98	0.89	2.1	331
16	10.7	A0 $\approx$		4246:			2.5	436	145	9.6	F2	A	4315				182
17	10.9	F5		4274:				251	146	10.7	dG0		4321	0.35	0.06	5.4	105
18	11.5	gK0						832	147	11.3	gG5						794
19	8.9	dG5		4415	0.40	0.29	3.6	105	148	10.2	F8		4293				132
20	6.8	F0		4295				60	149	8.8	gK0	K0	4497	1.05	1.72	-0.6	692
21	11.0	F2						347	150	10.2	F2		4269				240
22	11.4	gK5						794	151	10.2	F8		4293				132
23	11.1	gK2		4546:				759	152	11.4	gG8						759
24	10.8	gK0						603	153	9.7	F8		4318				105
25	10.4	gK0		4441				501	154	11.4	gK2:						
26	11.3	gK5:						692	155	10.1	F5		4245:				174
27	9.6	F8:		4345				100	156	11.1	F8						199
29	10.1	gK5		4564				436	157	11.1	F5						275
30	9.2	A2 $\approx$		4256			2.5	219	158	10.6	gG8		4475	0.77	0.71	2.0	479
32	10.2	gK5		4586				457	159	10.5	gG5		4408	0.58	0.62	1.7	525
114	8.1	gG5	K0	4432	0.63	0.55	2.5	120	160	10.1	gG5		4417	0.55	0.55	2.1	363
115	10.9	gG5		4415				661	161	10.5	F2		4269				275

B. D.	m_{ph}	Sp. U.	Sp.H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs	B. D.	m_{ph}	Sp. U.	Sp.H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs
83° 162	10.0	dG5		4373	0.46	0.19	4.7	105	83° 324	9.8	F2		4270				199
163	10.5	F8		4299:				151	325	10.1	F5		4280				174
164	9.4	F2	F0	4269				166	326	11.0	dG0						151
165	11.7	gM						912	327	11.1	gK0						692
166	10.8	gG5		4394	0.55	0.65	1.3	724	328	11.4	g:G8						
167	10.1	F8		4292				126	329	10.8	dG0		4324				138
168	11.0	dG0						151	330	11.1	dG0						158
169	10.8	F5						240	331		F8		4274				
170	9.6	F5		4288				138	332	10.0	gK5		4507				417
171	11.2	F8						209	333	10.6	F8		4298:				158
172	9.4	dG0	G5	4366	0.38	0.21	4.1	105	335	11.1	gK2						759
173	10.5	A0 κ		4274			2.5	398	336	8.8	gG8	G5	4419	0.77	0.77	1.7	240
174	10.6	F2		4282				288	337	10.0	A0 ϱ		4172			0.9	661
175	11.2	gK5:						724	338	10.8	F8		4331				174
176	10.7	F5		4283:				229	339	8.6	A2 κ	A2	4279			2.5	166
177	9.7	dG8	K0	4408				63	340	10.4	dG8		4444				87
178	9.2	gG8	K0	4459	0.96	1.18	0.7	457	341	11.4	d:G8						
179	10.4	gG8						479	342	10.8	dK0		4477				83
180	10.5	F5		4247				209	343	9.6	F8		4347				100
181	10.0	gK0		4475				417	344	10.8	gK2		4506				661
182	8.5	A3 κ —	B9	4262			1.9	209	345	10.1	dG0		4292	0.19	0.06	4.9	100
183	11.8	F2[A0]						501	346	12.0	gK5:						1047
184	10.4	F5		4266				199	347	11.0	gK2:						724
185	10.5	F5		4278				209	348	11.3	gK5						759
298	10.9	gG8		4462:				603	349	10.7	F8		4309:				166
303	10.5	F8		4280				151	350	9.5	F8		4341				95
306	9.8	gG8		4418	0.88	0.81	1.9	347	351	10.5	dG0						120
307	10.7	F8:		4273:				166	352	9.1	F2	G	4297				144
308	10.9	F8		4268:				182	353	10.6	gK0						549
309	10.6	F5		4276				219	354	9.1	A3 κ	A5	4290			2.5	209
310	11.6	dG0:						199	355	10.8	g:G5						
311	10.2	F2		4271				240	356	10.5	F8:		4305:				151
312	8.8	F5	F8	4274 4323:				95	357		Pl. nebula						
313	10.8	dG0						138	358	10.5	gG8		4434:				501
314	10.9	gK0						631	359	11.3	F8:						219
315	12.1	gM:						1096	360	11.1	g:G5						
316	10.9	A3: κ					2.5	479	361	10.9	dK0						87
317	11.2	g:K0							362	11.2	gG5						759
318	8.7	F8	F8	4306				66	363	10.6	gG5		4493:				575
319	10.3	dK0		4417:				72	364	10.5	dG0		4360				120
319	10.7	dK0		4409					365	9.5	F2	A3	4275				174
320	11.2	dG5						138	366	9.8	gG8	G5	4456				363
321	10.1	gG8		4441				417	367	10.6	dG8		4424				95
322	10.1	F8		4296:				126	368	10.2	F5		4296				182
323	9.9	dG8		4378	0.55	0.28	4.3	120	369	8.2	gK0	K0	4477	1.06	1.06	1.7	182
									370	11.2	F5						288

B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs	B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs
83° 371	10.8	F8						174	83° 522	10.9	F5						25
372	10.5	F8		4314				151	523	10.6	gG0		4374:				759
373	8.3	A0 κ	A0	4275			2.5	144	524	9.1	F8	G0	4304				79
374	10.4	F8		4303:				144	525	11.3	gG8						724
375	10.3	g:G5		4406					526	10.9	dG0		4300:	0.22	0.11	4.5	174
376	10.4	A0 κ		4270			2.5	380	527	8.0	dG0	G5	4339	0.22	0.26	2.9	95
382	11.4	gG8						759	528	10.5	F5		4270				209
479	10.8	F5		4233:				240	529	11.5	F8						240
481	9.8	A0 μ		4222			1.0	575	530	8.6	gG8	G5	4453	1.01	0.55	3.9	79
482	11.0	gK0		4421:				661	531	9.6	gK2	K2	4499	1.54	1.12	1.5	380
483	10.8	F8		4258				174	532	10.4	gG8		4458				479
484	11.5	gK0						832	533	9.1	A5	A5	4249				190
485	11.3	F8		4284				219	534	8.7	A5	F0	4255				158
486	10.3	gG5		4424				501	535	8.2	gG5	G5	4416	0.70	0.65	2.1	151
487	10.6	dG0		4336				126	536	6.2	A0 κ —	A2	4258			1.3	95
488	11.1	F5		4277				275	537	10.4	A0 σ		4155:			0.2	1096
489	10.8	gG8		4434				575	538	10.7	F0		4247:				363
490	11.4	gK2:						871	539	10.6	dG0		4318	0.37	0.00	6.0	76
491	11.0	F5		4271				263	540	10.8	F8		4307:				174
492	10.2	F8		4277				132	541	8.7	F8	G0	4297				66
493	9.6	gG8	K0	4432	0.93	0.80	2.3	263	542	9.6	gG5		4106	0.71	0.77	1.2	436
494	10.6	F2		4260				288	543	10.7	F8		4336:				166
495	11.3	gK0						759	544	9.5	A0 μ		4239:			1.0	501
496	11.1	F8						209	545	11.2	gG5						759
497	10.3	gG5		4416	0.65	0.65	1.8	457	546	10.9	gG8		4433				603
498	9.7	F2		4261				190	547	6.9	A2 κ —	A2	4267			1.9	100
500	11.7	gM						912	548	10.7	F8		4320				166
501	9.5	gK0	K2	4502	0.98	1.45	-0.1	759	549	10.3	F0		4261				302
502	11.3	gG5						794	550	10.4	gK0		4473				501
503	10.5	F8		4267				151	628	11.1	F8		4328				199
505	9.1	F5	G5	4246				110	629	11.7	gK5						912
506	9.7	F5		4254				144	630	7.3	A0 κ	A0	4249			2.5	91
507	10.9	gK2		4510				692	631	10.9	F8		4310:				182
509	10.6	dG0		4318	0.24	0.00	5.7	87	632	11.4	gK5						794
510	9.7	F8		4327				105	633	10.9	F8		4301				182
511	8.3	A0 μ	A2	4237			1.0	288	634	10.6	F8		4260				158
512	8.0	F8	F8	4280				48	635	9.6	F2		4272				182
513	11.5	gG8:						794	636	11.9	gG8:						955
514	10.8	F2		4248:				316	637	10.0	F8		4323				120
515	9.8	F8		4282				110	638	11.1	A5						479
516	11.1	A0 κ					2.5	525	639	11.9	g:K2						
517	10.7	F8		4272				166	640	6.1	gK2	K0	4561	1.68	1.58	1.5	76
518	11.2	gG8						692	641	10.4	F8		4287				144
519	10.8	F8		4337				174	642	11.3	A3 κ					2.5	575
520	11.3	gK2						832	643	10.5	dG0		4301				120
521	10.5	gK0		4498:	1.05	1.12	1.5	575	644	11.1	F8		4294				199

B. D.	m_{ph}	Sp. U.	Sp.H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs	B. D.	m_{ph}	Sp. U.	Sp.H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs
83° 645	10.8	dG0		4378				138	84° 16	9.4	gG8		4419	0.71	0.61	2.5	219
646	11.2	gK2						794	17	10.3	dG0		4333				110
647	7.5	A0 σ —	B9	4219			0.2	288	18	9.0	F2	F5	4289				138
648	9.7	F8		4301				105	19	10.6	gK2						603
649	10.1	A0 κ		4277			2.5	331	20	10.5	F2		4288				275
650	10.9	F2		4296				331	21	11.6	gK2						955
651	10.9	dG5		4344:				120	22	12.0	gK2:						1148
652	11.0	F5		4274:				263	23	9.5	gK0		4431				331
653	12.9	gM:						1585	24	9.7	F8		4288				105
654	11.0	F5		4283				263	27	10.0	A5		4261				288
655	11.1	gK5		4593				692	28	9.8	F5		4298				151
656	10.1	dG5		4355	0.41	0.35	3.0	240	75	10.6	dG0						126
657	9.2	F2		4281				151	76	10.6	F8		4326				158
658	11.9	gK0						1000	77	10.4	A0 κ		4226			2.5	380
659	12.2	gK2						1259	78	8.6	gK2	K2	4535	1.36	1.47	1.3	263
660	9.0	F5		4303				105	79	10.4	dG0		4334	0.28	0.00	5.8	76
661	10.7	A5		4338:				398	80	10.8	gG5						631
662	11.2	dG8						126	81	10.9	gK2						692
663	9.2	A0 κ		4289			2.5	219	82	10.1	F8		4284				126
664	11.7	gK5						912	83	9.0	A5		4273				182
665	10.6	A2 κ		4279:			2.5	417	84	11.3	F2:						398
666	10.0	F8		4373				120	85	9.1	F5		4299				110
667	11.0	F8		4351:				190	86	11.1	gK2						759
668	10.9	gK5		4565:				631	87	9.4	F5		4285				126
669	9.8	F8		4306				110	88	7.9	A2 κ —	A2	4266			1.9	158
670	10.3	A0 κ		4272			2.5	363	89	10.8	dG0		4339:	0.11	0.15	3.6	251
671	10.9	F2		4313:				331	90	9.5	A0 μ	A2	4264			1.0	501
672	10.6	gK0		4458:				549	91	11.0	dG0		4346:	0.28	0.00	5.8	100
673	10.9	gK5		4543:				631	92	11.2	gG5		4451:	0.71	0.77	1.3	794
674	11.4	gK5						794	93	9.2	gK2	K0	4544	1.50	1.29	1.8	275
675	11.5	gK0						832	94	10.2	gG8		4468	0.81	0.73	2.1	380
84° 1	11.0	F5		4312:				263	95	10.8	dG0		4347:	0.28	0.00	5.8	91
2	10.4	A0 κ —		4228			1.3	661	96	11.4	gMc						794
3	7.6	F0	A2	4280				87	97	8.8	F8	F5	4302				69
4	9.0	A0 κ —	A	4259			1.3	347	98	11.2	gK2						794
5	11.0	gG8		4375				631	99	10.5	gG8		4490:				501
6	10.8	dG0		4328:				138	100	10.8	F8						174
7	10.4	F2		4286				263	101	11.1	F8						199
8	9.9	F0		4276				251	102	11.0	dG5						
9	8.7	F2	G0	4291				120	103	10.7	gG5		4398:				603
10	8.7	gG8	K0	4430	0.65	0.65	2.0	199	104	10.2	gK0		4505:	1.05	1.18	1.2	575
11	11.0	gK5						661	105	11.4	gG8						759
12	9.9	F8		4292				115	106	9.2	gK2	K2	4510	1.35	1.48	1.3	347
13	8.6	A2 κ —	A2	4259			1.9	219	107	10.7	gG5		4314:	0.60	0.55	2.4	417
14	8.9	gG8	K0	4454	0.72	0.66	2.2	199	108	10.1	F8		4309				126
15	8.2	F2	A5	4276				95	109	10.7	dG0		4312	0.37	0.00	6.0	79

B. D.	m_{ph}	Sp. U.	Sp.H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs	B. D.	m_{ph}	Sp. U.	Sp.H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs
84° 110	9.4	gG8		4455	0.77	0.49	3.6	132	84° 156	9.7	dG5		4377				69
111	11.2	gK0						724	159	11.8	gK5						955
112	9.1	dG0	G	4308	0.19	0.00	5.5	48	231	11.0	F8:		4339:				190
113	10.7	dK0		4428:	0.75	0.17	6.2	72	232	10.3	F5		4286				190
114	8.8	F5	F5	4280				95	233	10.4	F5		4269				199
115	11.0	gG5		4463:				525	234	5.9	A5	A3	4280				44
116	10.4	gK0		4484				501	235	10.7	F5						229
117	8.9	F5	F5	4279				100	236	10.7	gG8		4478:				549
118	9.0	F5	F8	4273				105	237	9.1	F5		4272				110
119	11.0	F5						263	238	11.1	F8		4269:				199
120	10.2	F5		4282				182	239	9.6	F2		4243				182
121	11.2	A3 α		4265			2.5	549	240	10.8	gMb						603
122	11.0	F8		4313:				190	241	10.3	F5		4277				190
123	10.8	F5		4257				240	242	10.4	F5		4253				199
124	10.9	F8		4311:				182	243	10.4	dG0		4356	0.19	0.00	5.5	87
125	11.6	gK2						955	244	10.6	gK2		4428:				603
126	11.1	gK0						692	245	10.8	F8		4313				174
127	10.9	dG0						144	246	10.7	F2		4254				302
128	11.1	dG0		4316:	0.37	0.00	6.0	95	247	11.1	F5		4240:				275
129	10.9	dG0		4332:				144	248	11.7	dG0						209
130	10.2	F5		4257				182	249	10.4	F5		4269				199
131	11.2	F8						209	250	10.5	A0 α		4289			2.5	398
132	9.7	A0 σ —		4226			0.2	794	251	11.9	gK5						1000
133	10.7	gG8			0.67	0.55	2.8	347	252	9.7	gM	Ma	4529				363
134	10.6	dG5		4401:				105	253	11.1	d:G8						
135	8.2	gG5	G8	4382	0.59	0.55	2.3	138	254	11.4	gK0						794
136	9.4	A5		4251				219	255	10.2	gG5		4461	0.65	0.58	2.4	331
137	11.2	F8						209	256	9.4	dG0		4321	0.21	0.12	4.4	91
138	10.7	F8						166	257	10.6	dG0		4327				126
139	10.3	A0 ρ		4215			0.9	759	258	10.6	gG8		4454				525
140	10.9	F8		4340				182	259	11.2	dK0		4447:				100
141	11.8	gM						955	260	8.9	A0 σ —		4277			0.2	549
142	10.7	dG0		4319:	0.26	0.00	5.7	91	261	10.4	dG0		4336				115
143	10.5	dG0		4352	0.22	0.11	4.5	144	262	9.6	gG8		4321	0.91	0.77	2.3	263
144	11.7	gM		4273				912	263	11.6	dM						48
145	10.4	dG0						115	264	11.4	dG8						138
146	10.6	dG5		4400				105	265	12.1	gM:						1096
147	10.5	gK0		4348:				105	266	11.6	gK0:						871
148	11.6	gK0			0.77	0.65	2.6	347	267	10.6	A0 α		4245:			2.5	417
149	9.8	F2		4264				871	268	10.9	gK0		4515:				631
150	10.7	F5						199	269	8.6	F8	G0	4351				63
151	12.3	gM:						229	270	10.8	dG0		4357:				138
152	9.0	gK5	K0	4546				1202	271	10.3	F8		4324				138
153	9.8	F8		4293				263	272	11.4	F8:						229
155	10.9	gK0						110	273	10.4	F5		4312				199
								631	274	8.7	gG5	K0	4465	0.66	0.73	1.3	275

B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs	B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs
84° 275	9.8	gK5	K	4585				380	84° 366	10.0	A0 κ		4269			2.5	316
276	8.6	F5	F8	4335				87	367	11.5	gG8						794
277	11.4	dG0						182	368	10.5	F8		4278				151
278	11.2	F8						209	369	10.1	F0		4272				275
279	11.0	gM		4569:				661	370	9.2	gG8	K2	4440	0.70	0.53	3.1	151
280	11.3	dG0		4355:				174	371	9.4	gK5	K5	4556				316
281	10.9	gK2						692	372	10.5	F8		4304				151
282	10.8	F0		4289				380	373	11.2	gK0						724
283	10.7	gG8:							374	10.4	dG0		4318	0.19	0.11	4.4	144
284	10.2	dG5		4404	0.37	0.17	4.6	120	375	10.3	F8		4288				138
285	10.2	F8		4305				132	376	11.0	A0 κ		4297			2.5	501
286	7.9	dG0	G0	4344	0.35	0.07	5.4	29	377	9.8	F5		4282				151
287	10.6	dG0		4346				126	378	7.7	A0 κ	A0	4259			2.5	110
288	10.8	F5						240	379	11.0	gG5						692
289	6.3	A0 μ	A0	4251			1.0	115	380	11.0	dG0		4306				151
290	5.7	A0 ρ	A2	4283			0.9	91	381	10.9	dG0		4343:				144
291	9.7	F8		4334				105	382	10.7	dG5		4364				110
292	10.4	A0 κ		4336:			2.5	380	383	8.2	gG5	G5	4422	0.73	0.72	1.7	182
293	10.8	A2 κ		4319:			2.5	457	384	11.3	gG5						794
294	11.5	dG8							385	9.5	gG5		4429	0.59	0.57	2.2	263
295	11.3	dG0						174	386	10.9	dG0		4289:	0.28	0.17	4.1	209
296	9.4	gG8	K0	4481				302	387	9.4	gG5	K0	4433	0.71	0.55	2.9	182
297	10.5	F8						151	388	11.5	F0						525
298	10.5	F5		4318				209	389	8.7	A2 κ	A3	4274			2.5	174
299	10.5	F8		4293				151	390	11.5	gG8						794
300	10.5	gK0		4477:				525	391	8.9	dG0	G5	4307	0.31	0.00	5.9	36
301	9.7	gK0	K2	4479				363	392	11.1	F2		4238:				363
302	9.4	F2	F5	4274				166	393	10.3	gK0		4470				479
303	9.5	A2 κ	A	4285			2.5	251	394	10.6	dK0		4428	0.65	0.19	5.4	100
304	10.7	A0 κ		4238			2.5	436	395	10.7	F8		4310				166
305	9.5	gG8	G5	4448				316	396	10.7	F5		4252				229
306	11.0	F8						190	397	9.7	F8		4268				105
307	7.9	F5	F2	4294				63	398	10.0	F8		4276				120
311	7.9	dG5	G5	4370				30	399	9.6	F5		4272				138
352	8.3	F8	F8	4284				55	400	10.3	gG5		4439				501
355	10.6	F8		4339:				158	401	11.3	gK0						759
356	10.8	F5		4363:				240	402	11.3	F8						219
357	10.3	gK0		4516				479	403	11.0	dG5		4394	0.42	0.00	6.3	79
358	10.0	F8		4299				120	404	8.1	A0 κ		4243			2.5	132
359	8.9	F2	F2	4285				132	405	9.1	gG5	G5	4441	0.71	0.93	0.2	549
360	8.4	A3 κ	A5	4262			2.5	151	406	10.6	gG5	A0	4430	0.91	0.91	1.5	603
361	7.2	A2 κ	A2	4266			1.9	115	407	10.4	F5		4284				199
362	11.0	F5		4325:				263	408	9.6	F2		4253				182
363	10.8	F0		4300:				380	409	9.5	F8		4292				95
364	11.2	dG0						166	410	8.6	F2	F0	4264				115
365	9.6	gG8		4460	0.77	0.58	3.0	190	411	11.2	F5		4290:				288

B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs	B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs
84° 412	7.4	F5	F2	4259				50	84° 522	12.0	gM						1047
413	8.3	A5	A5	4257				132	523	8.4	F2	F	4297				105
414	10.5	F8		4269				151	524	11.1	g?K2						
415	9.7	gK2		4529	1.70	1.18	1.5	398	525	10.6	F5		4313				219
416	9.5	gG5		4419	0.55	0.71	0.8	501	526	11.2	A0 α					2.5	549
417	10.8	dG0		4316	0.19	0.00	5.5	105	527	9.5	F2		4276				174
418	10.5	F5		4274				209	528	9.5	F8		4320				95
419	11.1	gK0						692	529	10.4	dG5		4352				95
420	10.2	gG5		4452				479	530	10.9	gG8		4433:				603
421	10.3	F8		4299				138	531	12.0	gM:						1047
422	11.2	gG5?							532	11.3	gK5						759
423	8.8	F2	F0	4265				126	533	8.4	F0	A2	4272				126
424	10.6	gK2		4516				603	534	10.5	gK0		4463				525
425	9.4	F0		4250				199	535	9.6	F8		4335				100
426	9.0	F8	F8	4273				76	536	8.5	gK0	K0	4446	1.05	0.77	2.9	120
427	10.3	F2		4265				251	537	11.2	dG8						126
428	11.5	gK2						912	538	9.5	F0		4272				209
429	10.6	F8		4321				158	539	8.4	gG5	G5	4400	0.72	0.57	2.8	120
430	10.9	dG0		4373:	0.24	0.00	5.7	100	540	10.7	d:G5:		4432:				
431	9.7	d:G8		4388	0.55	0.31	3.4	166		11.3			4424:				
432	11.2	F5		4298:				288	541	10.8	F5		4303				240
433	11.0	F8		4280				190	542	9.9	F8		4333				115
434	11.7	gK2:						1000	543	10.5	gK5		4544				525
435	11.3	F8						219	544	11.9	gK0:						1000
436	9.2	F8	F5	4280				83	545	10.2	dG0		4279				105
437	10.3	gK5	K2	4561				479	546	8.2	F0	A3	4273				115
438	10.4	F8:		4294				144	547	10.3	gG8		4414				457
501	9.6	A2 α		4278			2.5	263	85°	1	9.6	F5		4303			138
504	10.8	F2		4277				316	2	8.8	dG0	G0	4325	0.06	0.00	5.0	52
505	8.6	dG0	G0	4360	0.17	0.26	2.6	144	3	9.7	gK5	K0	4549				363
506	10.6	F8		4343				158	4	12.0	gG5						1096
507	10.1	dK0		4404				60	5	10.3	F8		4296				138
508	10.5	F5		4316				209	6	10.9	gK0						631
509	8.0	gG8	K0	4436	0.63	0.73	1.2	209	7	10.0	gK0		4487				417
510	10.2	gG8		4466				436	8	9.8	F8		4307				110
511	10.6	dG0		4331				126	9	8.5	dK0	K0	4384	0.71	0.22	5.4	38
512	10.7	dG5		4337:				110	10	10.1	gK5		4551				436
513	7.9	gK0	K0	4471	1.13	1.05	2.1	132	11	8.4	A5	A2	4278				138
514	10.6	dG0		4325:				126	12	9.9	d:G8		4418				
515	10.5	F5		4291:				209	13	9.7	A2 α		4284			2.5	275
516	8.6	gMb	Mb	4431				219	14	10.1	dG5		4361	0.23	0.17	4.0	151
517	7.1	gK2	K5	4545	1.58	1.05	1.5	120	15	11.1	gK0						692
518	10.5	dK0		4403:				72	16	10.2	F5		4271				182
519	10.4	gK0		4443				501	17	10.0	F8		4293				120
520	10.4	F8		4298				144	18	10.1	gG8		4467				417
521	10.8	F5		4274				240	19	5.5	gK0	K0	4551	1.29	1.39	1.2	66

B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs	B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs
85° 20	9.5	gG8		4475	0.77	0.92	0.7	525	85° 85	9.5	F5		4274				132
21	10.7	gK0		4460				575	86	10.5	gG5		4438:	0.71	0.91	0.3	1000
22	10.6	gG8		4478:				525	87	9.8	gG5		4411	0.55	0.44	3.1	199
23	10.6	F8		4317:				158	88	11.0	F8						190
24	9.9	F5		4256				158	89	10.0	F8		4311				120
25	10.5	gG8		4476				501	90	11.3	gG5						794
26	11.7	gG8						871	91	9.6	F5		4276				138
27	11.2	F8		4409:				209	92	10.7	gG8		4459	0.91	0.94	1.4	661
28	10.7	dG0		4380				120	93	9.8	A0 κ —		4238			1.3	501
29	11.9	gK5						1000	94	9.6	gG5		4431	0.76	0.75	1.7	347
30	11.2	F5		4305				288	95	10.9	gK0						631
31	10.7	F5		4331				229	96	11.0	gG5						692
32	9.2	F5		4272				115	97	11.2	dG5			0.55	0.11	5.7	138
33	10.5	gK0		4513				525	98	9.6	gM	Ma	4529				347
34	10.7	dK0		4404:				79	99	9.2	gG5		4396	0.55	0.48	2.7	182
35	10.3	gG5		4470				501	100	10.5	gM		4568				525
37	10.7	F5		4290				229	101	9.1	A3 κ	F0	4255			2.5	209
38	9.7	A5		4294				251	102	11.3	gK2						832
56	10.1	A2 κ		4286			2.5	331	103	10.3	dG8		4387	0.58	0.06	6.3	58
58	11.0	dG0						151	104	11.0	gK0						661
59	9.7	dG0		4312	0.19	0.00	5.5	63	105	8.3	F8	F8	4280				55
		dG0							106	11.0	F8						190
60	11.5	gG5?							107	9.7	F5		4265				144
62	9.2	F5		4284				115	108	9.9	A5		4252				275
63	6.9	F8	F8	4329				29	109	10.9	gG8		4370:				603
64	9.2	F8		4320				83	110	10.7	gG5		4381:				603
65	8.6	F8	F5	4297				63	111	10.0	gG8		4480	0.77	0.73	1.9	380
66	10.8	gG5		4431	0.65	0.60	2.2	479	112	11.6	gK2						955
67	10.4	F8		4307:				144	113	10.7	F8		4372:				166
68	10.5	F2		4327				275	114	11.4	gM						794
69	9.4	A0 μ		4266			1.0	479	115	10.5	gK0		4503:	1.18	0.65	3.9	190
70	11.4	gG5						832	127	10.2	dK2		4477				46
71	11.4	dG5						151	154	9.9	F8		4307				115
72	10.5	dG5		4361				100	155	9.5	dG8	G5	4426	0.66	0.26	4.8	79
73	10.7	dG0		4354	0.17	0.28	2.4	417	156	11.7	gM						912
74	6.7	F0	A5	4306				58	157	10.0	dG8		4420	0.50	0.13	5.5	72
75	8.8	dK0	G5	4424	0.75	0.21	5.6	40	158	9.7	gG8		4473	0.81	0.83	1.5	398
76	10.5	F5						209	159	10.2	dG0		4336	0.03	-0.07	5.8	69
77	9.2	A2 κ —		4271			1.9	288	160	8.8	F5	G0	4296				95
78	6.5	A0 μ	A0	4254			1.0	126	161	8.1	dG5	K0	4395	0.55	0.17	5.1	36
79	10.4	gG5		4425	0.55	0.55	2.1	417	162	10.9	dG5		4390				120
80	7.5	gK5	K0	4561				132	163	11.2	F8		4315				209
81	8.5	gG8	G5	4462	0.76	1.05	0.0	457	164	10.4	F5		4280				199
82	9.6	dK2		4474	1.24	-0.25	6.7	35	165	9.6	F8		4342				100
83	9.6	A5		4280				240	166	9.2	gK0	K0	4477	1.08	0.63	3.7	115
84	9.6	gG5		4421	0.58	0.46	3.0	190	167	10.5	dG5		4352				100

B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs	B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs
85° 168	10.5	F5		4254				209	85° 214	9.5	dG5	G5	4337				63
169	10.5	F2		4290				275	215	10.6	A0 $\approx$		4235			2.5	417
170	9.5	gG5	G5	4426	0.65	0.63	2.0	288	216	11.2	gK0						724
171	11.4	gK2						871	217	10.1	dG0		4318	0.27	-0.04	6.1	58
172	11.1	gK5		4550				692	218	12.1	dG0						251
173	10.0	gG8		4463	0.75	0.77	1.6	436	219	10.6	F8		4295				158
174	11.4	gG8						759	220	10.5	F5		4282				209
175	10.9	gK0		4487				631	221	10.7	dG0		4319				132
176	10.1	F5		4267				174	222	7.6	F5	G0	4300				55
177	10.8	dG0		4335				138	223	10.1	dK0		4419				160
178	10.9	dG5		4325	0.50	0.11	5.5	110	224	10.2	gG8		4442				
179	10.9	dG0		4344				144	225	10.6	gK2		4510				603
180	10.9	F8		4295:				182	226	10.7	F5		4274				229
181	10.9	F8		4284				182	227	10.8	F8		4272				174
182	11.3	gK5						759	228	10.8	F2		4286				316
183	8.2	gG8	K0	4405	0.78	0.81	1.4	209	229	12.1	gK0:						1096
184	9.7	F8		4299				105	230	10.8	dK0		4403:				83
185	10.9	dG5		4367					231	11.0	gG8		4487:				631
186	10.6	F8		4314				158	232	11.0	dG5		4384				126
187	10.6	F8		4320				158	233	10.1	F5	G	4297				174
188	11.3	gK2						832	235	9.7	gK2	K	4534				398
189	9.8	F8		4333				110	266	8.9	F8	G	4289				72
190	9.6	F8		4312				100	268	10.7	dG0		4280				132
191	8.8	F5	F5	4278				95	269	6.9	F0	A5	4263				63
192	10.7	gK0		4480				575	270	11.3	gK2						832
193	10.4	dG0		4339	0.11	0.08	4.4	144	271	11.0	dG0		4323:				151
194	11.0	dG0		4313				151	272	10.5	F8		4318				151
195	11.0	gG8		4442				631	273	11.2	gG8						692
196	8.7	A5	A3	4278				158	274	10.5	dG0		4333	0.17	0.17	3.6	219
197	10.0	F8		4280				120	275	10.1	dG0		4331	0.19	0.06	4.9	100
198	10.8	dG5		4401:	0.33	0.00	6.0	83	276	11.0	gK0		4456:				661
199	10.1	gK0		4502	0.73	1.09	-0.2	1047	277	10.5	F8		4290				151
200	11.0	dG5		4384:				126	278	8.8	F8	F8	4299				69
201	10.7	dG5		4384	0.50	0.13	5.4	105	279	10.3	gG8		4469				457
202	9.8	dG5		4387	0.33	0.09	5.2	76	280	12.1	gG8						1047
203	10.9	gK5		4536				631	281	11.2	gK5						724
204	11.9	gG8						955	282	11.3	d?K0						
205	11.3	gK5		4519:				759	283	10.8	gG5		4442:				631
206	11.1	gG8						661	284	11.5	gK0						832
207	11.1	gG8						661	285	11.4	dG0		4328:				182
208	11.0	gK5		4567:				661	286	10.0	dG8		4421	0.69	0.00	7.1	35
209	9.6	dG0		4354	0.23	0.03	5.4	63	287	10.7	F5		4279				229
210	10.0	F8		4297				120	288	10.5	dG0		4332	0.28	0.00	5.8	79
211	10.1	F8		4311				126	289	10.5	gG5		4460				549
212	11.3	dG8						132	290	11.7	dG8	K0					158
213	9.4	F5		4260				126	291	11.7	dK0						126

B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs	B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs
85° 292	11.5	gG8						794	85° 368	11.2	dG0		4314				166
293	11.3	dG5						144		12.2							
294	7.6	F2	F0	4288				72	369	10.6	gG5		4416				575
295	11.7	gG5:						955	370	9.5	F5		4273				132
296	11.7	gG5						955	371	9.2	F5		4302				115
297	11.5	gK0						832	373	10.9	gK0:						631
298	12.5	gM:						1318	374	10.1	A2 κ		4270			2.5	331
299	11.2	F5		4308:				288	375	10.1	F8		4295				126
300	12.3	gK2						1318	376	8.9	A5	F0	4271				174
301	11.4	dK0						110	377	10.7	F5		4326				229
302	11.1	F5		4272:				275	378	10.3	dG8		4410				83
303	10.9	gG5		4421				661	379	11.7	dM		4577:				50
304	9.4	F8		4299				91	380	10.5	A5		4299				363
305	11.3	F2						398	381	11.7	gG8						871
306	11.5	gG5						871	382	9.9	F5		4285				158
307	10.5	F8		4312				151	383	5.2	A0 μ	A0	4232			1.0	69
308	11.5	dG5		4324:				158	384	7.6	gK0	K0	4488	1.18	0.99	2.4	100
309	11.2	gG8		4478:				692	385	11.6	gG5						912
310	11.1	F5		4293:				275	386	10.4	gK0		4457				501
311	11.2	F8						263	387	10.7	A5		4304				398
312	11.7	gG5						955	389	9.7	F5		4286				144
313	11.8	gK2:						1047	390	9.2	dG5	G5	4385	0.46	0.11	5.4	52
314	11.1	F8		4258				199	391	11.4	gG5						832
315	10.9	F8		4306				182	392	9.7	F5		4303				144
316	11.1	gG5						724	393	11.0	A3 κ		4283:			2.5	501
317	11.0	dG0		4356:	0.28	0.00	5.8	100	394	10.5	F8		4310				151
318	11.5	gG5						871	395	11.3	gG8		4471:				724
319	11.6	gG5?							396	10.1	A2 κ		4270			2.5	331
320	9.0	A0 κ —		4261			1.3	347	397	10.9	F0						398
321	11.2	dG0		4341				166	398	9.6	gK2	K2	4467	1.16	1.60	0.6	575
322	11.5	F8						240	399	6.7	F2	F0	4293				48
324	9.7	F8		4286				105	400	8.3	gG5	G5	4391	0.49	0.55	1.8	182
325	9.8	F8		4287				110	401	7.4	F5	F5	4275				50
326	11.5	gK0						832	402	10.0	F5		4272				166
328	11.4	F8		4296:				229	403	7.0	A2 κ —	A5	4258			1.9	105
329	9.0	gG8	K0	4470	0.77	0.58	3.0	144	404	10.8	dG5		4384				115
330	9.4	dG5	G5	4363	0.48	0.07	5.8	48	405	11.0	F5		4295				263
331	10.9	gK0		4507				631	406	8.6	A2 κ —	A0	4252			1.9	219
332	11.3	R		4591:					407	9.7	F2		4261				190
334	10.7	gG5		4473				603	408	10.2	A2 κ		4272			2.5	347
335	10.6	gK2		4530				603	409	6.7	A2 κ —	A0	4270			1.9	91
363	10.0	A5		4265				288	410	10.0	dG0		4337				95
364	9.6	F8		4306				100	411	10.1	F2		4254				229
365	11.5	gG8						794	412	8.7	dG0	F0	4282	0.03	0.13	3.4	105
366	10.0	gK0		4489				417	86° 1	9.9	A5		4255				275
367	8.8	A0 κ	A	4259			2.5	182	2	10.2	gK2		4537				501

B. D.	m_{ph}	Sp. U.	Sp.H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs	B. D.	m_{ph}	Sp. U.	Sp.H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs	
86°	3	10.5	dG0					120	86°	58	10.4	F5					199	
	4	10.5	F5					209		59	10.6	gG8					525	
	5	10.8	dG0					138		60	10.4	F8					144	
	6	10.7	gG8					549		61	11.4	gK5					794	
	7	9.1	F5					110		62	10.2	F5					182	
	8	10.3	F2					251		63	10.5	F8					151	
	9	8.6	A5	A3				151		64	9.1	A5					190	
	10	12.1	gK5:					1096		65	8.9	dG0	G5	4314	0.29	0.10	4.9	58
	11	10.0	F5					166		66	7.7	A0 ρ	B9	4233			0.9	229
	12	11.3	gG8					724		67	9.2	F5	G	4284				115
	13	11.3	F8:					219		68	10.6	F8		4289				158
	14	9.4	dG0	G5	0.06	0.13	3.5	138		69	10.5	F8		4299				151
	15	10.4	g:G5					4423		70	10.5	gG8		4462				501
	16	10.5	F8?					4362		71	10.7	F2		4257				302
	17	7.1	gK0	K0	0.92	0.88	1.9	100		72	10.2	gK0		4491	1.05	1.05	1.7	457
	18	10.1	gG8					417		73	10.5	dG0		4342	0.28	0.00	5.8	79
	19	10.6	F2					288		74	10.5	F8		4255:				151
	20	10.5	F8					151		75	9.5	F2		4247				174
	21	8.9	dG0	G0	0.39	0.14	4.8	60		76	10.9	F8		4265				182
	23	10.7	F0					363		77	9.7	gK0		4482	0.88	0.99	1.2	457
	24	11.4	gK0					794		78	10.5	F8		4334				151
	25	8.2	F5	F5				72		79	7.6	gK2	G5	4486	1.48	1.43	1.4	158
	26	10.4	F5					199		80	10.5	A0 κ		4247			2.5	398
	27	10.5	gK0:					525		81	11.0	gG8		4261:				631
	28	11.0	F5					263		82	11.4	F2:		4223:				417
	29	10.1	F2					229		83	10.9	gK0		4491:				631
	30	10.1	gK2					479		84	11.0	gM		4459:				661
	31	9.6	A0 κ —				1.5	457		85	11.0	F8		4273:				190
	32	9.7	dG8					63		86	9.3	F5	F8	4268				120
	33	10.7	gG8					549		87	9.9	F5		4275				158
	34	10.4	A5					347		88	10.5	F2		4260				275
	35	11.1	F5					275		89	11.6	gK2						955
	39	8.0	F0	F0				105		90	10.8	dK0		4461				83
	42	10.2	A2 κ				2.5	347		91	9.4	A0 κ	A	4279			2.5	240
	45	9.2	A5					199		92	9.5	dG0		4333	0.11	0.00	5.3	63
	46	9.9	F8					115		93	10.3	F8		4302				138
	48	10.4	F5					199		94	10.6	gG5		4460	0.73	1.31	-1.2	2089
	49	9.4	A0 κ —				1.3	417		95	10.8	F5		4283				240
	50	10.4	F8?							96	9.1	F8	G5	4291				79
	51	6.1	F5	F5				28		97	10.9	F8		4289				182
	52	9.6	A5					240		98	10.8	gG8:		4467				575
	53	11.3	gG5					794		99	11.4	gG8:		4360:				759
	54	8.9	A5	F0				174		100	10.4	dG0		4327	0.19	0.00	5.5	87
	55	9.6	F5					138		101	11.1	gG8		4471:				661
	56	10.4	F0[A2]					316		102	8.7	A0 μ	A0	4266			1.0	347
	57	10.6	F5					219		103	8.3	dG0	G0	4304	0.35	0.23	3.8	72

B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs	B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs
86° 104	10.5	dG0		4333	0.37	0.28	3.4	240	86° 168	10.6	F5		4290				219
105	11.1	gG8		4458				661	169	9.5	F5		4262				132
106	11.6	F5						347	170	7.5	F2	F0	4257				69
107	9.6	F5		4278				138	171	9.2	F5		4266				115
109	10.5	F8		4310				151	172	8.8	gG5	K0	4410	0.58	0.53	2.4	174
110	10.1	gM	Ma	4524				436	173	10.4	gK0		4488	0.95	0.95	1.7	501
111	10.8	F8		4313				174	174	11.7	gK0						912
112	10.7	dG0		4335	0.19	0.11	4.4	166	175	12.3	gK5:						1202
113	8.2	gG5	G5	4413	0.67	0.80	0.9	263	176	6.7	F8	F5	4328				26
114	10.8	F8		4355				174	177	8.9	F5	G	4253				100
116	10.2	gK0		4472					178	10.7	gK0		4485				575
117	10.5	gK0		4485				525	179	12.1	gK5						1096
118	11.3	dK0						105	180	8.9	A0 $\approx$	A0	4274			2.5	190
124	10.7	F0		4262				363	181	12.5	gK5						
127	10.3	gG5		4427	0.65	1.05	-0.8	1514	182	7.3	A5	F0	4270				83
129	10.5	F0		4255				331	183	10.6	dG0		4361:				126
132	9.9	F8		4389				115	184	9.4	dG0		4339	0.31	0.04	5.5	55
133	10.8	dG0		4346				138	185	11.3	F5						302
134	10.7	gG8		4456				549	186	10.9	dG0		4300:				144
135	11.2	gG5		4380				759	187	8.0	F5	F8	4294				66
139	10.7	F8		4310				166	188	10.2	F0		4254				288
141	10.6	F8		4339				158	190	10.6	F5		4289:				219
143	8.4	A2 $\approx$	A3	4276			1.9	199	191	9.5	F2		4266				174
144	10.8	F8		4324				174	192	10.5	dG0		4386:				120
145	11.3	gK0		4434				759	193	8.1	F5	F2	4278				69
146	9.2	A0 $\approx$	A0	4275			1.3	380	194	11.1	dG5		4418:				132
147	11.9	gK2:						1096	195	10.6	gK0		4480				549
148	11.0	dG0		4330					196	11.5	gK2		4498:				912
149	10.1	gG8		4460	0.71	0.81	1.1	575	197	11.6	dK0		4394				120
150	11.0	F8		4315				190	198	11.4	F8		4336				229
151	10.6	dG5		4378				105	199	9.2	F0	F5	4277				182
152	8.6	F2[A2]		4283				115	200	10.9	dG0		4347				144
153	11.3	gK0		4452				759	201	7.4	F2	F0	4285				66
154	8.6	F8	G0	4310				63	202	11.1	F5		4271				275
155	10.8	A0 $\approx$		4306			2.5	457	204	11.4	gG5		4382:				832
156	11.2	gG8		4399				692	222	9.5	dG0		4315				
157	10.6	gG8		4452				525	226	11.7	F8:		4422:				263
158	11.6	gG8:		4484:				832	227	11.1	gG8:		4465:				661
159	8.5	A5	A3	4284				144	228	12.3	dK2:						
160	10.2	dG0		4365	0.26	0.32	2.4	331	229	10.1	dG0		4340	0.40	0.13	4.9	100
161	7.4	A5	A2	4274				87	230	9.6	F8		4324				100
162	10.5	F5		4293				209	231	10.7	gG5		4478:				603
163	9.5	F5		4319				132	232	10.1	F8		4277				126
165	9.5	A5		4283				229	233	11.0	gG5:		4457:				692
166	10.6	F5		4273				219	234	9.5	F8		4298				95
167	10.5	dK0		4434				72	235	11.2	dG5		4383:				138

B. D.	m_{ph}	Sp. U.	Sp.H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs	B. D.	m_{ph}	Sp. U.	Sp.H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs
86° 236	10.8	F0		4269:				380	86° 283	10.6	F5		4252				219
237	11.3	gG8		4472:				724	284	11.6	gK2		4444:				955
238	12.4	gM						1259	285	10.8	F8		4284				174
239	11.0	F8		4281				190	286	9.7	F8		4282				105
240	10.9	gG8		4481				603	287	11.5	dG0		4348:				190
241	11.1	dG0		4365:				158	288	11.5	gG5		4447:				871
242	9.4	gG5		4432	0.80	0.70	2.2	251	289	10.5	gK0		4497				525
243	11.2	F8		4301:				209	290	9.4	F5		4263				126
244	8.7	A2 κ	A0	4283			2.5	174	291	10.6	F5		4280				219
245	11.0	F8		4288				190	292	11.3	F8		4295				219
246	10.1	F8		4307				126	293	10.3	F8		4304				188
247	10.6	F8		4315				158	294	11.4	F8		4261				229
248	11.5	d:G0		4352					295	11.0	dG0		4331				151
249	11.4	gG8		4470:				759	296	11.2	gG5		4469:				692
250	10.8	dG5		4405				115	297	9.4	F5		4279				126
251	11.5	gG8		4490:				794	298	10.6	dG0		4298	0.19	0.00	5.5	95
252	10.8	gG5		4442				631	299	11.1	F5		4298				275
253	11.3	gK2		4405:				832	300	10.3	F5		4270				190
254	10.2	F8		4283				132	301	11.4	F8						229
255	11.1	F5		4315:				275	302	11.6	gG5						912
256	9.1	gG8	G5	4453	0.88	0.80	2.0	240	303	9.8	gG8		4447	0.59	0.81	0.3	724
257	10.5	dG0		4335	0.19	0.00	5.5	91	304	11.0	A2 κ		4283			2.5	501
258	11.7	gG5?		4458:					305	10.5	F2		4268				275
259	11.3	F8		4318				219	306	10.8	dG0		4305				138
260	9.9	F8		4289				115	307	11.2	gG5		4461:				759
261	11.6	gG5						912	308	11.9	gG8:						955
262	11.0	gG5		4451:				692	309	11.9	gG5						1047
263	9.5	F8		4278				95	310	12.1	gK0?						
264	8.5	F2	F2	4261				110			gK0?						
265	11.9	gG5						1047	316	9.6	gG8		4466				331
266	10.2	dG5		4359	0.46	0.08	5.7	72	317	9.5	F8		4303				95
267	10.2	F5		4277				182	318	8.7	F2	F2	4268				120
268	10.7	F8		4316				166	319	7.3	A2 κ	A3	4268			2.5	91
269	4.4	A0 κ	A0	4255			1.3	42	321	10.2	A0 κ		4277			2.5	347
270	11.7	gG5		4396:				955	322	10.4	F2		4258:				263
271	10.5	F8		4270				151	323	11.3	gK5		4497				759
272	5.9	A2 κ	A3	4272			2.5	48	324	8.4	A5	A2	4267				138
273	11.2	F5		4254				288	325	9.6	dG8		4363				60
274	11.2	F8		4271				209		10.0			4391				72
275	8.6	gG8	K0	4461	1.08	0.81	2.8	132	326	10.3	gK5	K5	4548				479
276	11.5	F8		4278				240	327	10.1	F8		4280				126
277	9.2	A0 κ		4275			2.5	219	328	10.7	gG8		4464				549
279	10.5	dG0		4340	0.28	0.00	5.8	79	330	10.5	F8		4319				151
280	12.1	gK5						1096	331	10.4	F5		4280				199
281	9.6	gG5		4418	0.62	0.55	2.4	229	332	9.2	F2	F0	4255				151
282	8.1	gM	Ma	4532				174	333	11.1	A2 κ		4298			2.5	525

B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs	B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs
86° 334	9.9	A0 κ		4269			2.5	302	87° 56	10.6	F5		4270				219
335	8.0	A0 μ	A0	4244			1.0	251	57	11.4	F2:		4365:				417
336	11.8	gK2:						1047	59	11.5	F5		4260				331
337	11.1	F8		4277				199	60	10.9	gK0		4478				631
338	11.5	gG8						794	61	10.9	dG8:		4334				110
339	10.3	F5		4254				190	62	11.1	F5:		4260:				275
340	10.0	F0		4242				263	63	10.3	F8		4328				138
341	10.6	F2		4280				288	65	10.4	gG5		4371				525
342	10.4	F5		4276				199	66	10.8	gK2		4475				661
343	11.3	g?K0		4475:					68	8.9	F5	G0	4264				100
344	5.7	F0	F0	4277				36	69	9.7	dK0		4400	0.81	0.31	4.9	83
345	11.1	dG0		4342				158	71	9.2	F5		4254				115
346	9.5	dG0		4303	0.06	0.06	4.4	95	72	9.9	F5:		4266				158
347	7.9	F0	F0	4270				100	75	10.4	F8		4312				144
87° 1	9.0	A2 κ	A	4256			2.5	199	77	10.6	F8		4242				158
2	10.4	dG0		4367				115	78	8.4	F2	F5	4273				105
3	10.9	F8		4333				182	79	9.4	gG8	K0	4451	0.76	1.50	-1.2	1202
4	12.2	gM						1148	80	9.7	gG8	K0	4478	0.71	0.77	1.4	417
5	9.6	F8		4271				100	82	9.4	F2		4260				166
6	11.2	gG8		4470:				692	83	8.7	gG5	G5	4414	0.75	0.77	1.5	251
7	10.0	A5		4289				288	84	11.2	F5		4268				288
9	9.0	F0	F5	4278				166	85	9.1	gG8	K0	4412	0.84	0.71	2.4	199
10	11.2	F8		4330				209	86	10.4	gG8		4460				479
11	10.2	F2		4257				240	87	10.9	F8		4312				182
13	10.1	F5		4278				174	88	11.8	gK5		4483:				955
31	10.0	F8		4285				120	89	10.1	F5		4261				174
32	11.7	gK5:		4576				912	90	10.4	F5		4270				199
34	11.5	gG8		4454				794	91	10.9	gK0		4479				631
35	9.4	F5		4293				126	92	10.5	F5		4279				209
37	10.4	F8		4294				144	93	12.0	gK0		4491:				1047
38	10.1	F8		4284				126	94	10.0	F8		4284				120
39	10.5	dG0		4284	0.19	0.08	4.7	132	97	11.3	F8		4278				219
40	10.7	F2		4246				302	98	10.7	dG0		4343				132
41	9.5	gK5	K0	4567				331	99	8.8	dG5	G5	4335	0.38	0.02	6.0	33
42	11.3	F8		4323				219	100	9.6	F2		4275				182
43	11.1	gG8		4481				661	101	8.2	A2 μ	A2	4262			1.1	263
45	9.4	A3 κ		4251			2.5	240	102	9.6	F8		4283				100
46	9.1	gG5	G5	4425	0.67	0.62	2.2	219	103	10.5	gG8		4427				501
47	10.7	gK2		4504				631	104	9.0	gK0	K5	4471	0.91	1.05	1.1	347
49	11.0	F2:		4268				347	105	10.8	gG8		4483				575
50	11.1	gG8		4436				661	106	11.0	F8		4311				190
51	6.6	gM	Ma	4549				87	107	6.6	F5	F2	4286				35
52	11.3	dG8		4524:				132	108	9.6	F8		4283				100
53	10.7	gG5		4446	0.69	0.98	-0.2	1380	109	10.0	F2		4264				219
54	10.0	F5		4284				166	110	10.6	gG5		4427				575
55	10.7	F8		4328				166	111	10.8	F8		4289				174

B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs	B. D.	m_{ph}	Sp. U.	Sp. H.	λ_{eff}	$\log E_G$	$\log E_N$	M_{ph}	R parsecs
87° 112	9.9	F5		4302				158	87° 162	12.0	gG8:		4380				1000
113	9.5	F5		4274				132	163	10.6	F5		4240				219
114	11.7	F5:		4258				363	164	10.1	F8		4280				126
115	8.9	F5	F8	4273				100	165	10.1	F8		4287				126
116	10.7	dG5		4359				110	166	9.7	gK0		4447	1.14	1.05	2.1	302
117	9.5	F2		4262				174	167	11.5	dG0		4298				190
118	9.6	dK2	K0	4456	1.05	-0.09	6.7	35	169	8.4	A5	F0	4271				138
119	11.4	F8		4280				229	170	11.0	gG5		4394				692
120	11.0	dK0:		4459				91	171	11.0	gG5		4434				692
121	9.5	gG5	G5	4441	0.55	0.62	1.5	363	174	10.7	gG8		4458				549
122	8.6	F2	F2	4266				115	175	10.8	F0		4294				380
123	11.5	F5		4261				331	176	11.0	F5		4264				263
124	9.7	F0		4269				229	177	10.6	F5		4276				219
125	10.1	F5		4311				174	178	11.5	gG8		4420:				794
126	11.3	F8		4289:				219	179	11.0	F0[A2]		4262				417
127	10.2	A2 κ		4262			2.5	347	180	8.4	A5	A5	4252				138
128	10.2	F5		4325				182	181	8.5	A2 μ	A3	4246			1.1	302
129	9.8	gK0		4492				380	196	10.0	F5		4271				166
130	10.0	gG8		4452				398	197	11.6	F8		4266				251
131	10.7	gG5		4396				603	198	12.2	gM:						1148
133	10.1	gG5		4396				457	200	11.5	F8		4342				240
135	11.6	gK2		4507				955	201	8.6	F2	F8	4270				115
136	10.9	A0 κ		4258			2.5	479	203	11.4	gK0		4467				794
137	10.9	gG5:		4438				661	205	7.3	A2 κ	A2	4258			2.5	91
139	12.1	gK0:		4493				1096	206	9.6	F8		4266				100
140	11.4	F5		4300				316	207	10.8	F0		4269				380
149	9.9	gG8		4435				380	212	10.4	F2		4304				263
150	11.6	gG8		4457:				832	213	10.5	F8		4256				151
152	11.4	gG8		4462				759	216	11.1	F0:		4287				436
153	11.7	dG5		4415				174	217	8.9	A2 κ	A0	4246			2.5	190
155	10.9	gG8		4468				603	220	9.6	gG5		4432	0.67	1.05	-0.6	1000
157	11.5	gG5		4426				871	88° 61	10.6	F8		4279				158
158	10.2	dG0		4329	0.37	0.00	6.0	63	66	10.7	dG0		4295				132
159	11.2	dG0		4349				166	74	10.7	gG8		4463				549
160	10.8	gK0		4461	1.16	1.52	0.5	1047	80	9.0	A2 κ	A0	4254			2.5	199
161	11.0	gK0		4473				661									

Part II.

A. C.	m_{ph}	Sp. U.	λ_{eff}	R parsecs	A. C.	m_{ph}	Sp. U.	λ_{eff}	R parsecs	A. C.	m_{ph}	Sp. U.	λ_{eff}	R parsecs		
82°	39	10.3	g?G8	4276	83°	29	11.3	F2	398	83°	1092	10.8	F5	4286:	240	
	42	11.3	dG0	174		49	11.3	F8	219		1096	11.0	F8		190	
	47	10.5	A3 κ	4271		56	10.6	A3 κ	4253:	417	1147	12.2	gM	1148		
	105	10.9	A2 κ	479		57	10.9	A2 κ	4282	479	1537	10.8	F8		174	
	123	11.4	F8	229		58	11.1	gG5		724	1582	11.0	F2:		347	
	148	11.2	F8	209		59	11.1	gG8		661	1596	11.0	dG0		151	
	860	10.4	F8	4233		62	11.5	F5		331	1626	11.3	F8		219	
	884	11.0	F8	4260		64	10.9	F5		251	1630	11.6	F5		347	
	915	11.1	F5			66	11.7	F8		263	1631	12.2	F8		331	
	946	11.4	gG5	4352:		81	11.3	F5:		302	1676	11.2	dG0		166	
	975	11.0	dK0	4439		91	11.2	F5		288	1722	11.2	F5:		288	
	1118	10.9	F5	4250		102	11.2	F0		457	1723	10.5	F5		209	
	1125	11.0	F5	4263		148	11.9	F0		631	1739	11.2	F8		209	
	1126	11.2	F5	4250:		177	11.8	F5		380	2301	11.2	F0:		457	
	1127	11.3	F5	4251:		203	11.4	F8:		229	2303	11.6	F5		347	
	1133	11.1	F5	4276:		670	11.2	F8	4283	209	2407	12.0	F5		417	
	1134	11.3	F8	4235:		678	10.8	F8	4282	174	2408	11.7	F5		363	
	1145	11.4	F8			680	11.8	F5	4434:	380	2428	11.4	A5:		549	
	1176	11.4	F5	4290:		688	10.5	gK2	4420:	575	2429	11.0	A0 κ		501	
	1190	10.9	A0 κ	4196		692	11.4	d:K2			2456	11.6	F0		549	
	1202	11.1	F5			712	10.9	A0 κ	4219:	479	2491	11.5	F0		525	
	1203	11.6	F5			719	11.0	F8	4283:	190	2506	10.8	F5	4233:	240	
	1222	10.8	F5	4282		723	11.9	A0 κ		759	2550	11.2	F5		288	
	1232	11.0	F8	4248		771	10.8	F0	4260	380	2555	11.5	dG0		190	
	1249	10.9	F5	4278:		789	10.9	F8		182	2563	11.6	F0 κ		549	
	1820	11.0	dG0			804	10.9	F5		251	2576	11.4	F8		229	
	2915	11.4	F5	4296:		899	10.9	F5		251	2587	11.2	dG0		166	
	2917	11.1	A2: κ	4240:		927	11.5	F5		331	2616	11.1	F5		275	
	3030	11.6	F8			930	11.3	F8:		219	3576	11.5	A0 κ		631	
	3044	11.5	F0			947	11.9	d:G5			3665	11.8	F5		380	
	3053	11.6	F8			983	11.4	F5		316	3689	11.8	F8		275	
	3083	11.0	F0[A0]			994	10.9	F5		251	3700	11.8	F5		380	
	3088	11.2	A0 κ			999	11.6	F0:		549	3702	11.9	g:G5			
	3103	11.3	A0 κ			1015	11.2	F5:		288	3708	11.5	F5		331	
	3105	11.3	F0			1029	10.6	A3 κ	4241:	417	84°	1	10.7	dG0	4285	132
	3110	11.2	A5			1030	10.8	F5		240		30	11.0	F8		190
	4262	11.4	F8:			1036	11.6	dG0:		199		84	12.3	g:G5		
	4411	11.1	F8			1040	11.6	F5		347		92	10.8	dG0		138
83°	3	11.1	A0 κ			1042	11.7	F2		479		101	11.0	F8		190
	12	11.5	F5			1052	11.4	F5		316		103	11.2	dG5		138
	14	11.3	A5:			1059	11.8	gG5:	1000		111	11.1	F5		275	
	18	11.4	dG8			1081	11.3	dG0:		174		117	11.1	F5		275
	19	11.0	dG0			1091	11.0	F2		347		122	11.1	gK0		692

A. C.	m_{ph}	Sp. U.	λ_{eff}	R parsecs	A. C.	m_{ph}	Sp. U.	λ_{eff}	R parsecs	A. C.	m_{ph}	Sp. U.	λ_{eff}	R parsecs
84° 142	11.4	dK0		110	84° 1606	11.3	F5:		302	85° 157	11.6	F5		347
154	11.1	F5		275	1609	11.6	dG0		199	159	11.5	F5		331
171	11.2	F8		209	1613	11.6	dG0		199	288	12.0	gG0		1445
248	11.5	F0:		525	1645	12.4	F8:		363	299	11.6	F2:		457
621	11.5	F5	4194:	331	1646	11.4	F5		316	316	11.2	F2	4320:	380
626	11.2	A0 κ	4226:	549	1670	11.1	G0:			326	11.4	dG0		182
631	11.5	F5		331	1673	10.8	F5		240	328	11.4	F0		501
637	11.1	F8		199	1688	11.6	F8		251	338	11.4	A0 κ		603
645	11.1	F0 κ		436	1695	11.3	dG0		174	342	11.1	F2		363
666	11.4	F8		229	1696	10.6	F2	4313:	288	347	11.9	F5		398
691	11.7	gG8		871	2072	11.6	A0 κ		661	350	11.6	F5		347
703	10.9	A2 κ	4239:	479	2076	11.1	F5		275	361	11.3	F8:		219
726	11.1	F8		199	2080	11.4	dG0		182	366	11.6	F8:		251
765	11.7	A0: κ		692	2105	11.1	F8		199	386	11.4	F8		229
770	10.9	gG8	4480:	603	2133	11.3	gG5		794	404	11.2	gG5		759
788	11.0	F5		263	2236	11.6	A0 κ		661	441	11.6	F8		251
807	10.9	F0 κ		398	2318	11.3	F8:		219	442	11.2	dG5		138
812	11.2	A5		501	2517	10.9	dG8	4405:	110	487	11.7	F8:		263
822	11.5	F5		331	2524	11.7	gG5		955	494	10.9	F5		251
842	11.3	F8		219	3063	11.2	F8	4303:	209	499	11.2	gG0	1000	
844	11.6	F5		347	3081	11.4	F0		501	501	11.6	F8		251
868	11.4	F5		316	3110	11.3	F8		219	503	11.4	F8		229
870	11.3	F5		302	3120	11.3	A2 κ		575	515	11.5	F8		240
886	11.9	F8		288	3129	11.4	F0		501	517	11.7	F5:		363
887	11.6	F5		347	3151	11.7	A0: κ		692	519	11.0	dG0		151
897	12.2	F8:		331	3163	11.6	d:K0			520	10.7	dG0		132
898	12.1	F5		436	3177	11.2	F0		457	526	11.3	F5:		302
911	11.6	F2		457	85° 1	11.5	gG8		794	527	10.9	dG0		144
919	11.5	dG0		190	8	10.8	A3 κ		457	551	11.1	F2		363
932	11.5	gG8		794	15	10.4	A0 κ	4208	380	563	11.5	gG0	1148	
945	11.4	F8		229	22	11.4	gG5		832	577	11.7	F5:		363
993	11.5	F5		331	23	10.5	F2	4231:	275	579	11.7	gK2	1000	
1013	11.5	F2		436	33	11.2	F5		288	586	11.1	F5		275
1015	11.5	dG0		190	35	10.7	F5		229	588	11.7	gG8		871
1016	11.4	d:G5			37	12.3	gG5		1259	589	11.7	F5		363
1073	11.3	F5		302	56	11.2	dG0		166	593	11.3	gK0		759
1079	10.9	F8		182	63	11.4	gG5		832	607	11.1	F8		199
1088	11.3	gG0	1047		84	11.5	F8		240	646	12.0	F5		417
1101	11.6	F8:		251	86	10.9	gG8		603	658	11.2	A5	4286:	501
1120	11.4	F8		229	123	11.6	gK2:		955	718	10.8	F2		316
1130	11.5	F5		331	131	10.8	dG8		105	764	11.8	F5		380
1144	11.5	dG0		190	138	10.5	F8		151	769	11.5	F8		240
1151	11.5	F5		331	139	11.1	gK2		759	803	11.6	F5:		347
1158	11.5	A5:		575	141	11.5	F5		331	847	11.3	F5	4288:	302
1162	12.1	F5		436	145	11.7	F2		479	850	12.0	F8		302
1578	11.1	dG0		158	149	11.6	F2		457	871	11.5	F5		331

A. C.	m_{ph}	Sp. U.	λ_{eff}	R parsecs	A. C.	m_{ph}	Sp. U.	λ_{eff}	R parsecs	A. C.	m_{ph}	Sp. U.	λ_{eff}	R parsecs
85° 1052	11.3	F8	4312	219	86° 30	11.8	F8		275	86° 1251	11.7	F8	4227:	263
1056	11.5	dG5	4377	158	39	11.5	F5		331	1255	11.7	F8	4269:	263
1071	11.3	F8		219	41	11.1	F5	4289	275	1256	11.8	F8:	4278:	275
1115	11.5	F5	4276	331	46	11.6	F8		251	1291	11.7	F8		263
1191	11.3	gG0	4397:	1047	55	12.1	F8		316	1361	12.2	F5:		457
1307	12.2	gG8		1096	64	11.3	F8		219	1397	12.0	d:G0		
1374	11.0	F5	4332:	263	65	11.8	gG5		1000	1607	11.6	F0:	4335:	549
1379	11.0	F8		190	69	11.2	F8	4334:	209	1608	11.3	F8:	4268:	219
1405	11.4	F8	4261:	229	103	11.4	dG5	4337:	151	1648	11.5	F8		240
1579	11.1	A5:		479	144	11.6	F5	4310:	347	1656	11.7	F8	4380:	263
1604	11.5	F8	4294:	240	200	11.6	F8:		251	1659	11.2	F8	4290:	209
1605	11.1	F8	4320:	199	201	11.2	gG5	4234:	759	1675	11.9	gG5		1047
1608	11.7	F0		575	214	11.3	A0 κ	4283	575	1687	11.2	F8	4238	209
1615	12.5	dG0?			227	11.0	F5	4234:	263	1704	11.5	F8		240
1616	12.3	dG0?			240	11.3	F2:	4242:	398	1709	11.7	F8		263
1617	11.6	F5		347	252	11.4	F5	4266:	316	1720	11.5	F8		240
1621	11.1	F8		199	271	10.7	A3 κ	4268	436	5312, 16	11.5	d:G5		
1623	11.5	F8	4403:	240	274	11.3	gG5	4288:	794	(p. 926)				
1625	12.1	gG0:		1514	288	10.9	F2	4287:	331	5315, 65	11.4	F8		229
1626	11.6	F0		549	321	11.5	F5		331	(p. 926)				
1631	11.2	F2	4276:	380	359	10.8	dG0		138	5961, 2	11.8	gG5	1000	
1634	11.4	F8	4315:	229	373	11.0	F8		190	(p. 927)				
1647	11.2	F2	4318:	380	409	11.1	F2:		363	5961, 13	11.5	F8		240
1673	12.5	gG5:		1380	434	11.2	F5	4514	288	(p. 927)				
1692	11.6	F5		347	452	11.2	dG0	4282:	166	5961, 42	12.1	F5		436
1695	11.4	F8		229	463	11.0	F2	4306:	347	(p. 928)				
1696	11.3	F5:		302	497	11.2	dG0		166	5951, 74	11.6	dG0		199
1712	11.7	F0:		575	537	11.3	F5	4263	302	(p. 929)				
1771	11.6	gG8		832	539	11.0	F2	4282:	347	5951, 75	11.1	F8		199
1774	11.5	A0: κ		631	570	11.3	F8	4300	219	(p. 929)				
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